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The Editors Note . . .

WHILE at the printer's last month putting the January issue to bed, we were presented an astronomical question by several members of the plant personnel who take more than a passing interest in our copy; during the week, many persons elsewhere wanted to know the same single fact: "Which planet is nearest to the sun?"

It turned out that by Saturday of that week most of Boston was aware of the value of the question, for Station WNAC was then offering over $100 for its answer. Of course, knowing the answer did no good unless one were equally fortunate in being called by the station announcer in the course of a daily 15-minute program, but as each call increased the prize by $5, the accumulation during the week indicated at least 20 Greater Boston families in which this simple astronomical question was unanswerable.

Saturday morning's program was pretty exciting, especially when one mother of a large family preferred to let her brood continue sleeping (at 9:15 a.m.) than take a chance one of them might know the answer to a question worth $100. Sixty seconds was given for the answer after the question was put, and anyone in a family might supply the information, so there was even time for research! Our expectancy was that if mother or dad didn't know (or had forgotten), then surely any child attending school would have this information at hand. On the final call that morning, however, when a girl answered the phone, it was her mother who knew Mercury as more than just the mythological messenger of the gods.

All of which seems to us to indicate that astronomy is still far from occupying the place it should have in grade school and high school programs. To be sure, Mercury is the elusive planet, but we venture to state that fewer persons could explain the phases of the moon, the causes of the seasons, or tell where the sun rose at a particular season—relatively significant events in our lives.

In this connection, it is encouraging to read (see page 10) of what is probably a model astronomy program, though apparently quite brief, described by Mrs. Elanora B. Davis, teacher in a Washington public high school, and also an amateur astronomer. The "one unit of astronomy" seems to be particularly well planned and presented. But it is to be regretted, on the other hand, that so basic a science receives attention only as part of a general science course.

Sky and TELESCOPE

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LETTER TO THE EDITOR

Sir:

Under date of November 26th, Pfc. George Shenkar, whose previous letter from a bit of Germany was quoted in your November editorial, writes to the undersigned:

"I received your letter of November 9th yesterday, and I now hasten to answer. I was very much surprised to hear of the whereabouts of my last letter, since I haven't received the November issue of **Sky and Telescope.** Receiving mail is of a varying nature; thus, at present, my mail is very scarce, but I hope the situation will improve shortly.

"Perhaps it may surprise you to see this letter typewritten. This is a captured enemy machine which I have temporarily acquired until it becomes too burdensome to carry around. The name of it is the 'Europa Schreibmaschine.'

"Since I have a bit of time for writing at this moment, I would like to relate an experience of an astronomical nature. This occurred back in Western France. We were traveling to a new destination one night, keeping very alert for enemy aircraft, which during that period were very active in bombing and strafing convoy routes. As the sky got darker, one could occasionally glimpse a meteor streaking across the sky. Finally, as it became very dark, one could not help but notice an unusually great number of meteors, in fact my commanding officer became quite alarmed at the spectacle. To add to the effect, most of the meteors seemed to come from the direction of the enemy positions, which were outlined by a line of burning towns in the vicinity. Recalling the date, however, I assured the officer that the display was nothing more serious than the annual Perseid meteor shower. It was even better the next night. Just after my return from guard duty, I obtained a pair of 6x field glasses and did a little observing. The sky was extremely clear that night; I saw the Andromeda nebula more clearly than I ever saw it in the States.

"At present, my observations have been reduced to nil. Day and night, if it isn't raining, it's cloudy. Clear days are few and far between.

"This is all I have to write at present. Please accept my heartiest wishes for the holiday season. I wish the same to the Detroit Astronomical Society and all its members and friends."

Perhaps this fighting amateur astronomer's letter may interest other readers of your magazine.

MARGARET BACK, secretary
Detroit Astronomical Society

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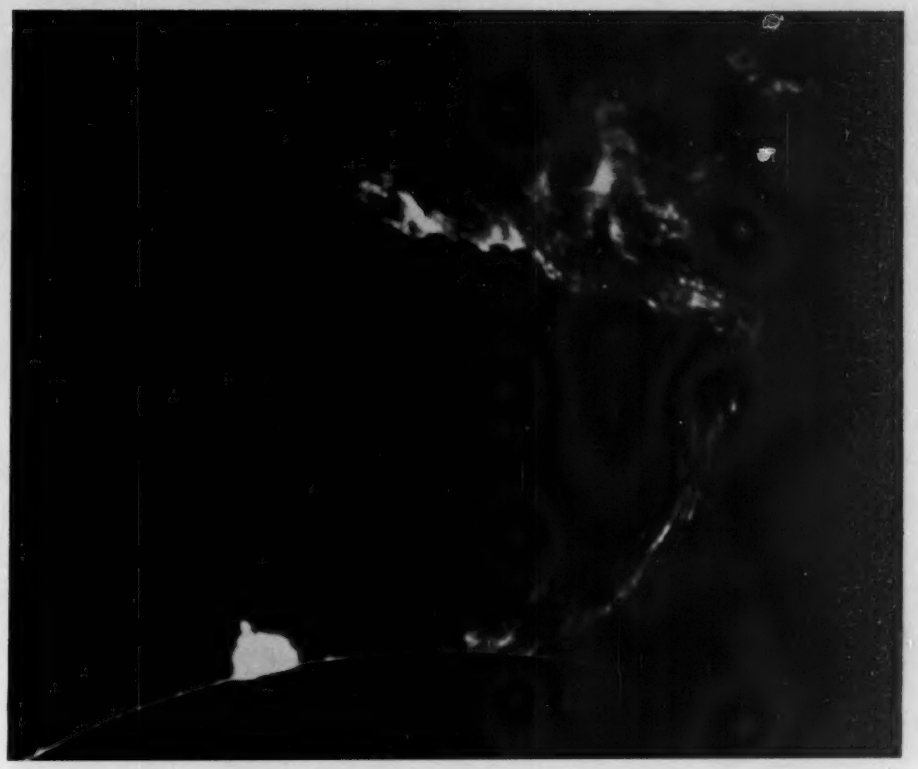


An unusual prominence photographed with the Harvard coronagraph, in the light of the hydrogen alpha line at 6563 angstroms.

ARTIFICIAL ECLIPSES OF THE SUN

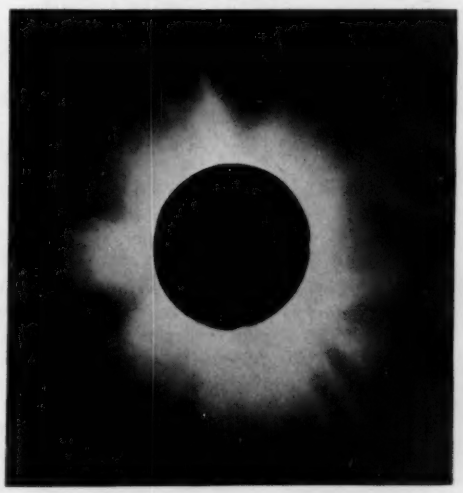
By Walter O. Roberts
Harvard College Observatory

An ancient Chinese imperial proclamation quoted by Mitchell provides that in case of error in the prediction of eclipses, "being before the time the astronomers are to be killed without respite, and being behind the time they are all to be slain without reprieve." Fortunately, astronomers are no longer subject to such drastic regulations. Yet concern with eclipses of the sun, though of a different nature from that of old, continues to be profound. In antiquity, and even to the very threshold of what we consider modern culture, total obscuration of the sun by the moon has carried ominous import to the people visited, evoking dire superstitious fears, and giving rise to elaborate rites designed to free the sun from the occult influence of the evil, devouring monster, the moon.

Today, however, we view a solar eclipse not with fear but with awe. To us it is a well-explained natural phenomenon of great beauty and of immense scientific importance — of importance because during total eclipse the solar chromosphere, the prominences, and the corona become spectacularly visible, and because we have reason to believe that these features of the sun are of vast significance to our understanding of the physical processes in the sun and the effects of solar variations on the earth itself. During the brief moments of a total eclipse we can investigate the chromosphere, prominences, and corona with the powerful tools of modern astrophysics: the camera, the photometer, and the spectrograph.

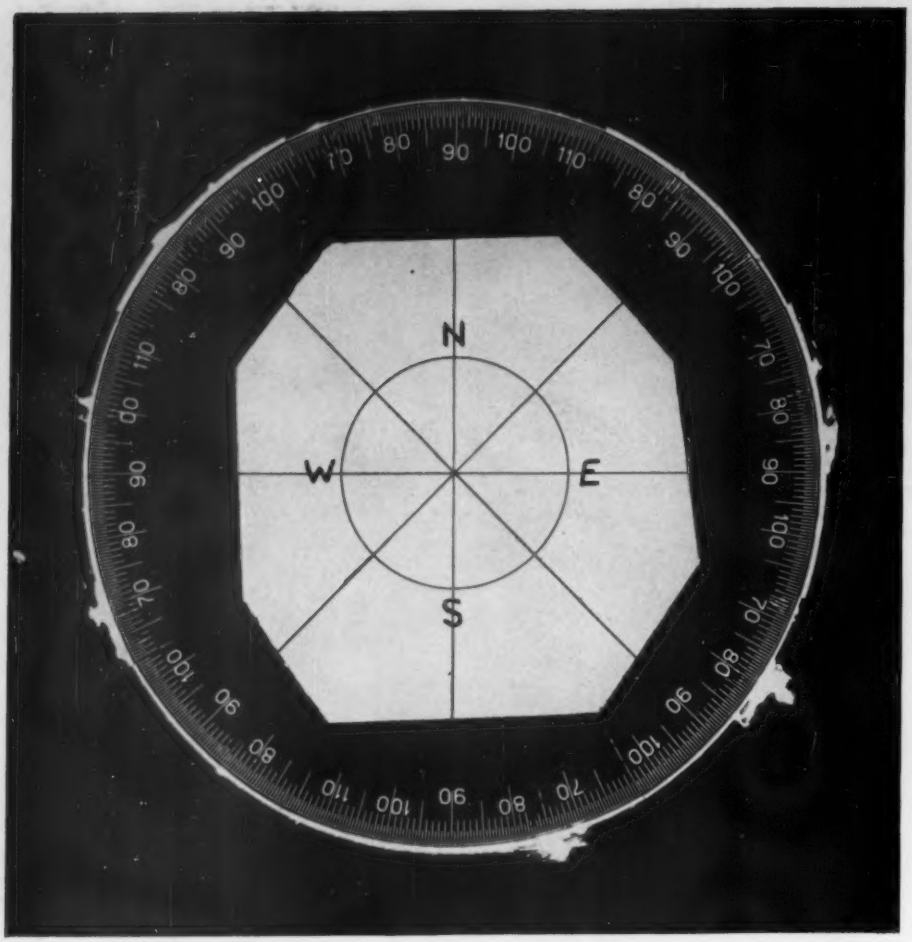
A glimpse of the prominences and corona during total eclipse is a thrilling sight. The brilliant, irregularly shaped prominences owe their scarlet color to the bright red spectrum line of incandescent hydrogen gas, though spectroscopic analysis shows other pronounced lines present, such as the yellow line of helium originally thought to be the well-known pair of sodium lines, and the strong, violet lines of calcium near the limit of the short wave end of the visible spectrum. The bright, uniform arc of the chromosphere is similar to the prominences in color and constitution. The pale, greenish-white, more nearly symmetrical, and diffuse light of the corona, on the other hand, originates in a far more complicated physical situation. It has a continuous spectrum not entirely unlike that of the sun, on which is superposed a strong bright-line spectrum with prominent lines in the green and the red. These arise in highly ionized iron atoms whose existence in that state implies exceedingly high temperatures—over a million degrees centigrade — and which also implies extremely strong invisible ultraviolet radiation which may possibly produce important effects on the earth.

It is easy to understand why astronomers are anxious to be able to study these features without waiting for eclipses to occur. In our attempts to understand the physics of the stars, it has been a great handicap to us that the one conveniently located nearby star, the sun, is eclipsed so infrequently, and for such short duration at such widely scattered points on the earth's surface. But probably we should not complain, for had the moon been only a bit smaller or only a bit farther away it could not have succeeded at all in producing total eclipses, and then we might not yet have detected the prominences or corona.



The corona of the sun, photographed at the eclipse of 1937.

The first successful observations of the prominences without a solar eclipse were made independently by Janssen and Lockyer in the year 1868. They were able to view the prominence spectrum and to get some idea of the prominence shape and size by widening the opening of their spectroscope slit. A little over 20 years later the spectroheliograph was invented independently by two noted astronomers, Hale in America, and Deslandres in France. The new instrument made it possible to photograph the



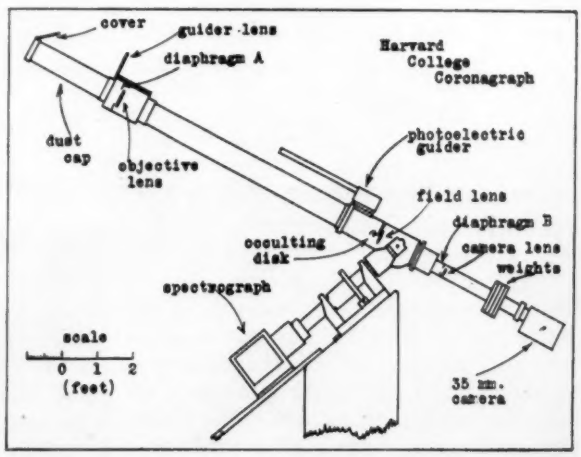
Prominence photographs pasted up to represent the whole circumference of the sun. Each print of the eight original negatives is mounted at the correct angle to represent a certain 45-degree section of the sun's limb.

prominences by scanning the image with the slit of a spectrograph, and by simultaneously moving a photographic plate placed at the spectrograph focus directly behind another slit adjusted to pass only the light of the desired spectrum line. At the present time powerful spectroheliographs are in use at a number of observatories throughout the world. One of the most highly developed of these is located at the McMath-Hulbert Observatory in Michigan, where the apparatus has been perfected to permit rapid-sequence photographs of the prominences, and also of the remarkable features of the sun's disk which can be photographed with a spectroheliograph.

The corona, however, has not yielded to simple spectroheliographic investigation. Seventy years passed between Janssen's first prominence observation without eclipse and Lyot's first detection of the corona without eclipse. The story of the repeated attempts of many of the greatest astronomers of the times to photograph the corona is a fascinating one. Among those who were disappointed in their efforts were such men as Huggins, Bond, Harkness, Copeland, Tacchini, Todd, Giel, Wright, von Gothard, Deslandres, Ricco, Hale, and Blunck. Indeed, so discouraging was the repeated failure of astronomers to photograph the corona or its spectrum that in 1929 the following statement appeared in the technical literature:

"It is therefore completely hopeless to try to photograph the corona, except during eclipse, even in the farthest red or from high mountains."

One year later, in 1930, Dr. Bernard Lyot, of Meudon Observatory in France, succeeded where all others had failed. At the suggestion of Professor H. O. Barnard, Lyot had investigated in detail the sources of unwanted sunlight scattered into the image of the artificial eclipse produced when an occulting disk is placed at the focus of a telescope lens. So startling was Lyot's achievement that some astronomers actually doubted for a while that Lyot had really photographed the solar corona rather than simply some spurious flare. But it is easy to understand now why he had succeeded where others had not. Lyot had analyzed carefully all sources of scattered light within a telescope and found that ordinary telescopes diffused many hundreds of times the amount of light that the corona radiated into them. He then set about to design a telescope, now known as the Lyot-type coronagraph, which completely eliminated or greatly reduced all of the deficiencies of the ordinary telescope for coronal photography. Lyot's work in developing this instrument is one of the outstanding achievements in the history of experimental astronomy.



The operating principles of a coronagraph may be understood by referring to this schematic diagram. Lyot discovered that in an ordinary telescope sunlight is scattered into the image from the following sources: diffraction of light from the edges of the objective-lens cell; reflection from the second face of the objective lens to the first and then a second reflection back into the image; diffraction around dust particles on and imperfections of the objective lens. Any one of the three sources is enough, usually, to render an ordinary telescope useless for coronal photography. The first two may be eliminated completely and simply. The third may be reduced by employing the very highest skill in making the telescope objective and in cleaning it. Diffraction at the edges of the objective lens can be eliminated by placing a diaphragm (A) with a sharp edge in front of the objective, and by means of the field lens focusing an image of this diaphragm (thus focusing the diffracted light) on diaphragm B, just in front of the camera lens. If diaphragm B is slightly smaller than the image of diaphragm A, all scattered light from the first source will be eliminated. By proper design of the objective, its multiple reflections can be brought to a point at diaphragm B, and eliminated completely by a small screen in the center of B. The objective lens images the sun on the occulting disk, and the camera lens in turn images this artificial eclipse at the 35-mm. camera film. A mirror may direct the image into the spectrograph.

A view of the Harvard coronagraph station in the summer. Photo by Otto Roach.

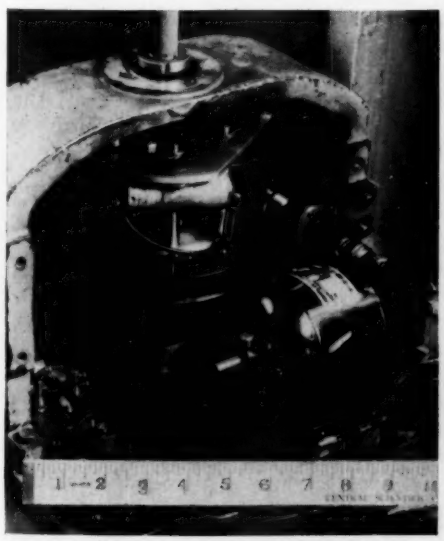
Since 1930 Lyot has improved his coronagraph in minor details, and has constructed a larger and more powerful instrument, now on the Pic du Midi in the Pyrenees Mountains of southern France. About six years ago, Dr. Max Waldmeier, who had worked for a time with Lyot, installed a coronagraph at Arosa in Switzerland, where he now operates it. Slocum and Pettit, of Mount Wilson Observatory, built a Lyot-type telescope about 1932 and used it for prominence photography, but not for coronal studies. In 1940, the Harvard College Observatory installed a coronagraph at Climax, Colo., high in the Rocky Mountains, near the old mining town of Leadville. These are the only coronagraphs of the Lyot type to be built thus far. An ingenious electronic instrument known as a "coronaviser" (see *The Telescope, 7,* 54, 1940) was developed by Dr. A. M. Skellett, of the Bell Telephone Laboratories, but the instrument has not yet been used in conjunction with a Lyot-type coronagraph, without which its value for coronal studies is dubious.

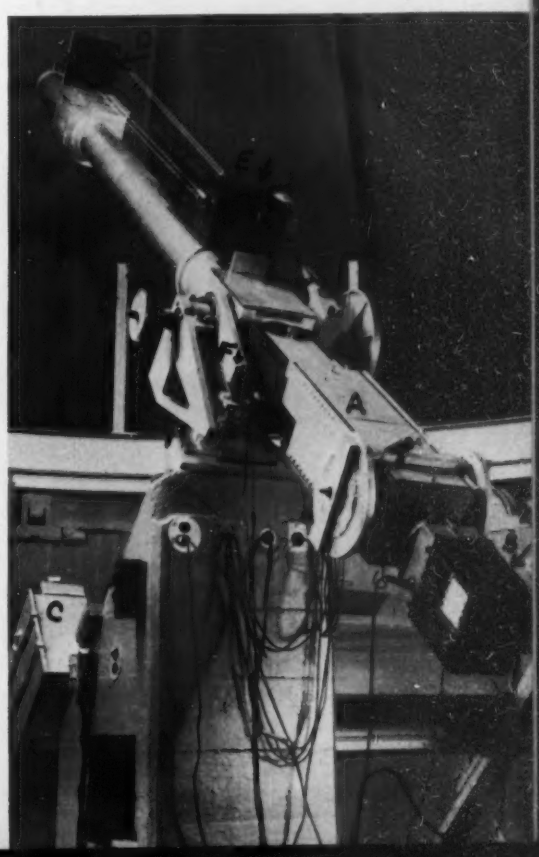
Harvard's coronagraph is housed in the highest permanent astronomical observatory in the world, at an elevation of 11,520 feet above sea level. The coronagraph is a 5-inch aperture instrument with primary focus of 100 inches. The construction, which closely follows the principles set forth by Lyot, was supervised by Dr. Donald H. Menzel, and its operation has been intrusted to me since the establishment of the Colorado station.

The need for clean, dry, and rarefied atmosphere imposed stringent conditions for the location of a coronagraph. The site chosen for our coronagraph in the Rocky Mountains enjoys frequent precipitation to clean the air, and at the same time offers a large number of clear days. The observatory is just below timber line at one edge of the community of homes maintained by the Climax Molybdenum Company for its mine employees. The observatory and residence lie directly on the Continental Divide, so that the peak of the roof forms, at this point, the watershed between the Atlantic and Pacific Oceans. The observatory dome has a unique conical shape, as the photographs show, to prevent snow from gathering upon it.

The climate at the Climax station is very severe, with the ground usually covered with snow from October until early June, and with snowstorms and freezing temperatures likely to occur any month of the year. During the brief summer, a profusion of very beautiful wild flowers decorates the mountainous landscape, and they are so hardy that snow and ice do not injure them. Local jokes are built around the theme that many a miner misses the summer entirely by working underground both days. And all the misfortunes and accidents that befall Climax residents are ascribed to the altitude, which is higher than the level at which fliers are usually advised to begin breathing the extra oxygen they carry in their airplanes.

The Harvard coronagraph is fitted with a direct camera and with a spectrograph, so that the records of the corona and prominences consist of direct photographs of any chosen feature or photographs of its spectrum. The direct photographs must be taken with light of a limited color range, because it has not yet been possible to construct an achromatic corona-





(Left) The photoelectrically controlled right ascension telescope drive. The motor in the foreground is electronically controlled to correct, by means of the worm gearing shown, the constant-rate synchronous drive mounted on the rotating platform. The housing is temperature regulated by the thermostat above "2" on the ruler.

(Right) The coronagraph and spectrograph. The camera tube is at A; within it are the Evans quartz-polarization monochromator and the camera lens. At B is the 35-mm. film transport mechanism. The spectrograph is at C. D and E indicate the guider lens and the photoelectric control unit for keeping the telescope automatically aimed at the sun. The declination drive mechanism is at F.

graph lens of sufficiently high quality to equal the simple lenses available. If a relatively wide band of wave lengths is desired, ordinary color filters may be used; but generally it is desirable to photograph in the light of an extremely narrow band, since diffused sunlight consists of all colors, and the prominences and corona can best be seen in the practically monochromatic light of specific spectrum lines.

For photographing in the light of narrow spectrum lines a spectroheliograph could be used. With the Harvard coronagraph, however, we use a newly developed astronomical tool known as the interference-polarization monochromator. This remarkable instrument acts as a practically monochromatic filter. The one now in use at Climax transmits a band of color only about six or seven angstrom units wide, as compared with several hundred angstroms for the best colored-glass filters. The monochromator which we use was built for us by Dr. John W. Evans, who has developed the theory of such instruments to a considerable degree, and has designed some still sharper and more versatile "filters" which we hope soon to be able to build. Briefly, the monochromator consists of a multiple-layer sandwich of polaroid and quartz. Each quartz unit is cut so that it produces constructive light interference for some given set of wave lengths which permits these to pass through, and destructive interference which stops the wave lengths between these. A number of such units are made so that their constructive interference wave lengths agree for only one or a few values, and for all other wave lengths destructive interference stops the light in one or another layer of the sandwich. With the monochromator we use a specially manufactured Eastman Kodak film of extreme sensitivity with specific color characteristics.

The remarkable feature of such a unit is that it can be built into a small container only six inches long, and that when such a monochromator is placed in front of the film in a coronagraph it will act in much the same fashion as a spectroheliograph, but with no moving parts, and no narrow slits to adjust. The units so far completed do not possess quite the versatility of a spectroheliograph, but for application in a coronagraph their simplicity and compactness are great advantages, and the image quality which can be transmitted through them certainly equals or exceeds that of spectroheliographic apparatus.

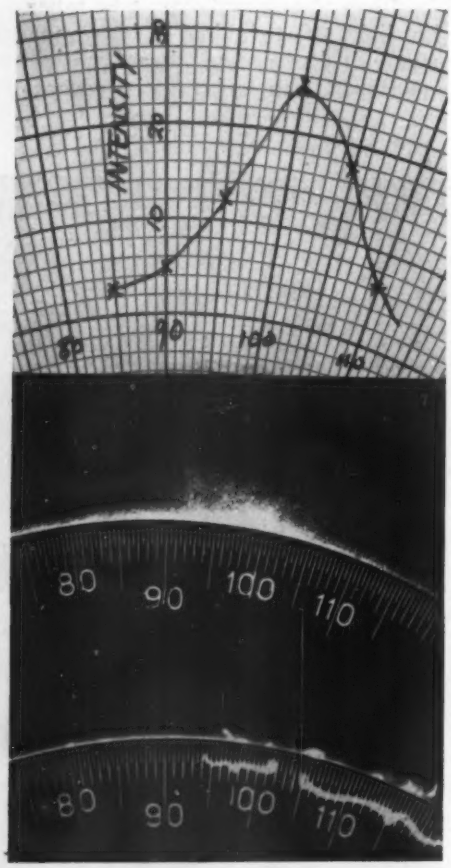
A large, violently active prominence which showed very turbulent internal motions.

The prominence photographs accompanying this article have all been taken with the coronagraph, and most of them with the interference-polarization monochromator. Lyot has also designed and used such monochromators, and much credit for the development of these "filters" must be given to him. With his apparatus he has taken some remarkable sequence photographs of the corona. Pettit at Mount Wilson likewise uses equipment similar to the Evans monochromator which we employ. Pettit's apparatus has been used exclusively for prominences.

The highly critical element of a coronagraph is obviously the objective lens, for any tiniest flaw in its polish or any smallest air bubble or other imperfection in the glass will scatter sunlight into the coronal image. We have, thus far, been able to obtain for our coronagraph only two objectives of quality adequate for satisfactory coronal studies. One was made by Dr. James G. Baker at Harvard College Observatory, and the other by the Perkin-Elmer Corporation, makers of precision optical equipment. Dr. Baker is now experimenting with the manufacture of an achromatic coronagraph lens.

We have taken thousands of feet of 35-mm. sequence pictures of prominences which can be projected as motion pictures for analysis of the motions. Such films were first taken by Dr. Robert R. McMath with the spectroheliograph, and they provide highly spectacular records of the turbulent and complicated forces acting in the prominences.

With new equipment which we are planning to build we hope to be able to produce similar motion picture records of the sun's corona; and when this information is added to that which we are already assembling regarding the day-to-day variations in the corona, we shall have a vast array of observational knowledge with which to attempt a definitive explanation of the mysterious and complicated phenomena observed at a total solar eclipse.



Three simultaneous observations of the same region of the limb of the sun. The graph at the top shows the intensity of the green coronal line at 5303 angstroms, obtained from a spectrogram. The intensity units are arbitrary; the curved slit of the spectrograph was placed parallel to the sun's limb at a height about 1/16 inch above the image of the occulting disk in the picture below.

An actual photograph of the corona at the same position, with an uncertainty of about three degrees in the angular scales. This picture (middle of three parts of figure) was taken through the interference-polarization monochromator, designed and built by Evans, and adjusted to photograph the light of the green coronal line.

The lowest picture shows the same position in the light of the prominence line of hydrogen alpha. This was also taken with the Evans monochromator.

NEWS NOTES

By Dorrit Hoffleit

WHO OWNS THE METEORITE?

Suppose you found a meteorite. Would it belong to you or to the owner of the land where you discovered it? Apparently numerous lawsuits have been fought on this question, which is discussed in *The Mineralogist,* June, 1943 (as referred to in *Star Dust,* National Capital Amateur Astronomers Association, Nov., 1944). In Iowa, where many meteorites have fallen, it has been decreed that "meteorites belong to the owner of the land on which they fall." Should any fall on United States government property, they are to be deposited in the Smithsonian Institution.

MANY HAPPY RETURNS

In October, William Gaertner, famous precision instrument maker, celebrated his 80th birthday. The organization of which he is the founder, president, treasurer, and general manager, as well as its leading scientific genius, befittingly observed the occasion and presented Mr. Gaertner with an oil portrait of himself.

Astronomers the world over appreciate the fruits of Mr. Gaertner's devotion to his chosen vocation. The delicate problem of surveying the distances of the stars, to mention but one random example, would not have progressed nearly as fast but for his accurate long-screw measuring engines. Astrophotometers, zenith telescopes, spectrohelioscopes, heliometers —innumerable instruments and devices requiring exacting accuracy— have been designed and built by Mr. Gaertner and the Gaertner Scientific Corporation. We are happy to acknowledge a debt of thanks to a man who helps make "exact" astronomy possible.

A METEOR REPORT

On the morning of last August 18th, the residents of our Middle Western states were surprised by a daylight meteor. Co-operation between the American Meteor Society and Science Service with its associated newspapers resulted in about 250 reports being received on this meteor. Dr. Charles P. Olivier, in his monthly "Meteor Notes" in the December issue of *Popular Astronomy,* gives the results of an analysis made by Edith F. Reilly, now at the U. S. Naval Observatory, and himself.

The extreme length of the meteor's path, 546 kilometers, and its apparition when only the sun could be used as a reference for position in the sky, resulted in very few persons being able to give precise values for its path across the sky. Observations made toward the end of the path, however, were helped by a long-lasting train. Dr. Olivier selected five points along the path for his solution: beginning point (seen by very few observers), point of first explosion, point of second explosion, end point, and ground point. The azimuth or direction of the path was accurately established by a plot of the positions of those who reported the path as vertical to the horizon — the meteor passed or would have passed through their respective zenith points. The slope of its path was also well determined, and found to be rather small.

The visible portion of the fireball's path began at 82° 12′ west and longitude 40° 02′ north, at an altitude of 166 kilometers. It ended over 88° 12′ west and 38° 44′ north, when 31 kilometers high. If fragments landed, they probably will be found near 89° 26′ west and 38° 27′ north, which would be in the vicinity of Parkersburg in Richland County, Ill. Dr. Olivier thinks the possibility of finding such fragments is good. The lack of reports from that part of Illinois near and beyond the calculated end point has been a handicap in the solution.

The present report, in addition to giving the numerical results of the solution for the orbit of the meteor (which is presumed to be parabolic), includes interesting details of the fireball's brilliancy and apparent size, the explosions and smoke train, and sounds heard by persons fairly near the path. All colors of the rainbow were reported, with a tail of hot, colored gases 10 to 15 times as long as the head's diameter. At the first explosion, the head separated into two or three pieces which continued straight on their course; the second explosion appeared to cause general disintegration of the main part. The smoke train, visible only from points near the path, lasted from 20 to 30 minutes, and changes in it indicated a probable low-velocity wind in the layer of the atmosphere in question, blowing from the northwest. Loud sounds were heard at Bicknell, Carlisle, Paoli, Sullivan, Terre Haute, Ind., and at Lawrenceville, Ill., as well as at other points in this vicinity.

COSMIC STATIC

A sheet-metal mirror, 31.4 feet in diameter with a focal length of 20 feet, is used by Grote Reber at Wheaton, Ill., to investigate electromagnetic energy at radio wave lengths coming from the sky. While the mirror is fixed at a given altitude, an automatic recording device traces out the intensity of the energy received of a given wave length (1.86 meters). The corresponding frequency is 160 megacycles a second. About 200 charts showing the relation between intensity and time—consequently, the right ascension of the region toward which the mirror was pointing—were obtained in 1943.

An analysis of these observations revealed stronger "static" when the mirror was pointed toward dense Milky Way regions and less energy farther from the galactic center: most static was recorded in Sagittarius, least in the Milky Way for Perseus, which is opposite the center region.

In Focus

OUR front and back covers this month are one of and one from Harvard College Observatory's Fremont Pass station at Climax, Colo., high in the Rocky Mountains. A story of this station and some of its work is on page 3.

The unique conical steel dome on the building housing the coronagraph is designed for best freeing the dome of the frequent and heavy snows. Any one or more of the six observing apertures can be opened independently of the others, so that the ones remaining closed protect the telescope from gusts of wind.

In describing the front cover picture, Dr. Walter O. Roberts writes: "To obtain this early winter photograph, I donned my skis and slid down the hill a suitable distance. As I set up the camera the tripod legs sank from sight, leaving the camera practically in the snow. When I climbed from my skis to see what could be done, I sank to a correspondingly awkward depth. So I struggled back onto the skis and up the hill to locate three small pasteboard boxes which I inverted and forced gently into the snow. Each formed a stable foundation for a tripod leg."

The striking back-cover photograph, taken with the coronagraph on January 4th this year, shows a remarkably large and active prominence. The streamer motion near the center of the photograph was in opposed directions. Several hours after the picture was made, a brilliant streamer erupted from the center right out of the top of the region shown. This reproduction is from a print enlarged from the original negative on 35-mm. film, and taken in the light of the hydrogen alpha line.

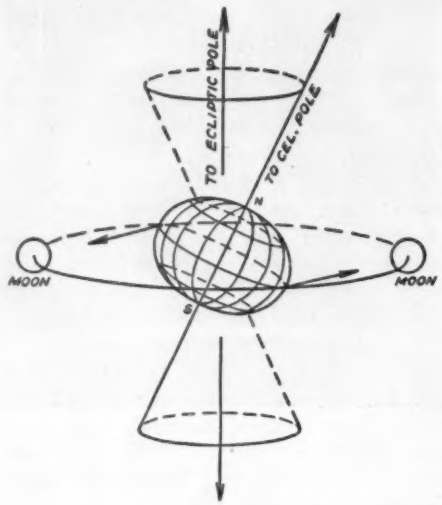
THE GREAT YEAR or The Cycle of Precession

By H. Porter Trefethen, Editor, *Maine Farmers' Almanac*

IN a general way, the Great Year equals the cycle of precession and we often see it referred to as about 26,000 years, but to be of practical value it must have a definite beginning and a precise measure of duration. Hipparchus, the "father of astronomy," was the first to make accurate observations of the stars, of which we still have a record. His division of the zodiac into 12 equal constellations or signs is still in general use. He is believed to be the discoverer of precession, and it is fitting that the zodiac of Hipparchus, B.C. 120, should mark the beginning of the Great Year.

The term *tropic* is from a Greek word which means "to turn," and involves both a time and a place. The time is when the sun reaches its farthest south (or north) declination and turns north (or south). This occurrence determines the length of the tropical year (year of the seasons), which Simon Newcomb has calculated to be 365.242 198 79—0.000 000 0614 (t-1900) days. This year begins when the mean sun is at the south tropical colure (winter solstice), which in turn determines the first point of Capricorn, for which the Tropic of Capricorn is named.

Because of precession, the first point of Capricorn is constantly moving westward along the ecliptic at a rate which Newcomb has calculated to be 0°.013 9601 + 0.000 000 0616 (t-1900); a complete circuit is made in 24,664 tropical years. Using these formulas, the time required for the solstices and equinoxes to pass through the respective signs and constellations is as follows:



The moon's (and the sun's) attraction for the earth's equatorial bulge causes the gyration of the earth's axis known as precession.

Tropical year and day	*Day of the Great Year*	*Calendar date**	*Precession*	*Zodiacal constellation*
0 — 0 Wed.	0	B.C. 121, Dec. 25	0°	First of Capricorn
2157 — 345 Wed.	788,127	A.D. 2038, Dec. 1	30	Sagit.-Scorpius
4295 — 202 Wed.	1,568,917	4176, July 10	60	Scorpius-Libra
6413 — 102 Sat.	2,342,399	6294, Mar. 31	90	Libra-Virgo
8511 — 287 Thu.	3,108,862	8392, Oct. 2	120	Virgo-Leo
10591 — 215 Tue.	3,868,493	10472, July 19	150	Leo-Cancer
12653 — 50 Wed.	4,621,456	12534, Feb. 10	180	Cancer-Gemini
14696 — 332 Sun.	5,367,926	14577, Nov. 9	210	Gemini-Taurus
16723 — 127 Mon.	6,108,065	16604, Apr. 16	240	Taurus-Aries
18732 — 326 Sun.	6,842,034	18612, Oct. 31	270	Aries-Pisces
20725 — 358 Sat.	7,569,992	20606, Nov. 29	300	Pisces-Aquarius
22703 — 4 Sat.	8,292,084	22583, Dec. 6	330	Aquarius-Cap.
24664 — 102 Thu.	9,008,420	24545, Mar. 11	360°	First of Capricorn

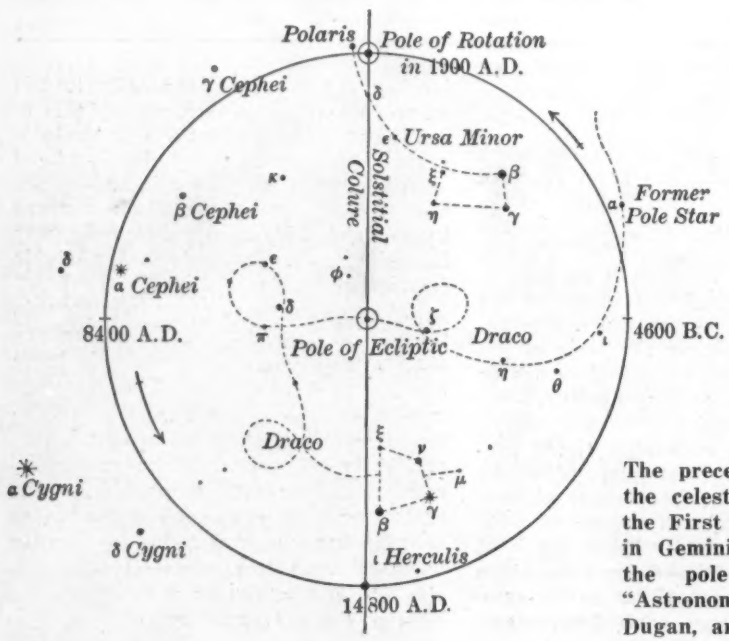
*The Julian calendar before A.D. 1582, Oct. 5, Friday; afterwards the Gregorian calendar.

Thus, the winter solstice will shift through all the zodiacal constellations with a corresponding change in the stars associated with each season of the year. Less than 100 years from now will complete the shift of 1/12 of the zodiac since the time of Hipparchus. In the first table the numbers in the second column differ by 1,677,586 from those for the Julian Day used by astronomers.

It is further interesting to note that the length of the tropical year at the end of this cycle will be 365.240808 days, whereas at its beginning the length is 365.242323. The year of the Gregorian calendar is 365.24250 on the average, or about 26 seconds too long at present. This error will gradually accumulate, so the date of the winter solstice will eventually fall in November.

As the actual length of the tropical year becomes less, the 26 seconds' difference between it and a Gregorian calendar year increases to as much as 146 seconds a year, which is why the dates fall back more rapidly near the end of the cycle.

These facts appear from a study of the second table, below. Dates in both tables may be compared with those on the diagram showing the pole stars of the future.



The precessional path of the celestial pole. When the First of Capricorn is in Gemini, Vega will be the pole star. From "Astronomy," by Russell, Dugan, and Stewart.

Tropical year of Great Year	*Date of solstice*	*Length of tropical year*
0	B.C. 121, Dec. 25	365.242323
2000	1880, Dec. 21	.242200
2100	1980, " 21	.242194
4000	3880, " 20	.242077
6000	5880, " 19	.241954
8000	7880, " 18	.241832
10000	9880, " 17	.241709
12000	11880, " 15	.241586
14000	13880, " 13	.241463
16000	15880, " 11	.241340
18000	17880, " 8	.241218
20000	19880, " 6	.241095
22000	21880, Dec. 3	.240972
24000	23880, Nov. 30	.240849
24664	24544, " 29	365.240808

BEGINNER'S PAGE

Man and His Expanding Universe — XIV

By Percy W. Witherell

OBSERVATIONS by many astronomers, made during more than a century, resulted in the discovery of thousands of hazy objects, galaxies, nebulae, star clusters, and the like, which are recorded in Dreyer's *New General Catalogue* (1890) and its supplements. A plot of the galaxies in this list showed a very uneven distribution in different directions. Whether this was real, or due only to the non-systematic arrangement of the regions that had been under observation, was not definitely established until the Shapley-Ames catalogue was compiled in 1932.

In this catalogue, the positions and photographic magnitudes of all such objects down to magnitude 12.8 were determined for the entire celestial sphere. A plot of these 1,249 galaxies shows 823 on the north side of the Milky Way and 426 on the south side. There are almost none recorded along the Milky Way, because the interstellar dust along our galactic plane completely obscures or seriously decreases the brightness of objects beyond that dust, so that such objects appear fainter than the limit of the catalogue. Giant galaxies away from the Milky Way are recorded to a distance of 20 million light-years, dwarfs to about four million, with an average of 10 million for the list.

In the northern part of the constellation Virgo, and stretching over into Coma Berenices, about midway between Arcturus and Regulus, is a concentration of 100 bright galaxies known as the Virgo cluster. None of these is visible to the naked eye, as they are eight million light-years away. The Shapley-Ames list includes only the giant Virgo galaxies. If fainter magnitudes to the 15th are included, the number in the cluster is doubled. In the vicinity are many more galaxies scattered through Lynx, Coma, and Ursa Major, in a region 40 degrees in length. Fortunately, this group is located in a position for favorable observation, in that space absorption is not especially troublesome. About three fourths of the galaxies are spirals, the rest spheroidal, with a few irregular members similar to the Magellanic Clouds. The cluster as a whole is receding from us at the rate of 700 miles per second. The individual members are very active, some moving at speeds of 1,500 miles per second inside the group.

The total mass of this aggregation of galaxies is so enormous that the individual members average 200,000 million suns. As this seems too large for the observed luminosity of the group as a whole, it is possible that a considerable amount of the mass is composed of non-luminous matter in the intergalactic spaces. Although the spectra of some of the galaxies show the presence of groups of hot blue stars or very bright nebulae, the average spectrum is like the sun's.

Southward of the main group of the Virgo cluster, there are many galaxies that extend over 30 degrees toward the constellation of Centaurus. Northward are many more galaxies, as mentioned, and these are of about the same luminosity and distance. Are all these part of a great cloud of galaxies, of which our local group of 11 objects is a small condensation and the Virgo group a much larger concentration? If so, the cloud extends over three million light-years.

In the southern skies in the constellation of Fornax are 17 galaxies which undoubtedly are interrelated. The brightest member, NGC 1316, is of the spheroidal type, and nine of the 17 galaxies are spheroidal. Other galaxy groups are similar in having a spheroidal as their brightest member.

Last month, we noted the existence of the gigantic galaxies of Andromeda and our own Milky Way system, surrounded by the medium and dwarf galaxies in our neighborhood group. Although the smaller galaxies are not observed in the distant clusters, it is a fair assumption that they exist among the large types which we do observe. The evidence seems to be that the brightest and faintest galaxies in a group are about two and a half magnitudes brighter and fainter, respectively, than the average. We observe the brightest portion, and use this hypothesis to estimate the total luminosity of the group, and so its distance. It is found on the average that the absolute magnitude of the fifth brightest galaxy in a group is —16.4, and with this assumption and that galaxy's apparent magnitude, the average distance of the group can be determined with fair accuracy. It is better to use the fifth brightest than the first brightest galaxy in a cluster, for then the chances are much less that a bright foreground object has been accidentally chosen.

By this method, 25 clusters of galaxies with as many as or more members than the Virgo system have been measured. There are 100 groups with numbers similar to our local group. There are thousands of irregular condensations that suggest mutual association. Double and triple galaxies in close gravitational relationship are common. Some of these are of similar type, others are as dissimilar as a spheroidal alongside one of the Magellanic Clouds would be.

We have previously suggested that a survey of the outside systems would help us understand our own galaxy. Conversely, the range from double stars through all degrees of association up to the famous globular clusters that we find in our own system has counterparts among the distant objects of the metagalaxy.

Galaxies in Coma Berenices, photographed at Mount Wilson Observatory.

Amateur Astronomers

DECEMBER OCCULTATION OF VENUS

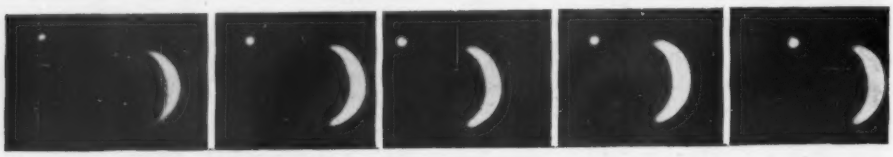
MOSTLY cloudy weather seems to have spoiled observations in the south of the occultation of Venus on December 18th. Several observers, however, reported partial or complete success.

Talbot Feild, of Texarkana, Ark., at latitude about 33°, notified his local paper the event would happen. "For a while," he writes, "it looked like a miss, but my 'reputation' was saved. Complete immersion took place at 8:25 p.m. C.W.T., and emersion began at 8:46 p.m., so Venus was invisible for 21 minutes. The local paper carried notices Saturday and Monday, and there was much popular interest in the phenomenon."

Mr. Feild sent a pen-and-ink sketch of his observations. Latimer J. Wilson, of Nashville, Tenn., sent a series of photographs which are reproduced here. He writes:

"Thick clouds and low altitude quite effectively obscured the occultation of Venus on December 18th. However, prior to the main event, clear spaces between sheets of stratocumulus clouds permitted five photographs to be secured, showing the changing positions of the moon and Venus.

"Careful measurement of these photographs indicates that immersion occurred about 23° from the north cusp of the crescent. The location here, 86° 44′ west longitude, and 36° 11′ north latitude, enabled a rough computation that the time of immersion should be at 8:20 p.m. C.W.T., December 18th. Measurements of the photographs gave $8^h\ 22^m\ 13^s.4$. The moon at that time was near obstructions which, with approach of more clouds, made observation of the occultation impossible."



Venus approaching occultation, as photographed on the evening of December 18th at Nashville by Latimer J. Wilson. The times, p.m. C.W.T., were 7:00:30; 7:19:00; 7:40:45; 7:45:55; 7:50:35.

ASTRONOMY IN THE WASHINGTON PUBLIC SCHOOLS*

ONLY one unit of astronomy is taught in the Washington public high schools. This is offered in the first part of the first semester of the ninth grade to those students who elect to study general science. The unit is called, "The Sky Challenges Man." Its theme is: "The universe consists of a great number of orderly systems."

The topical outline begins with the study of the solar system. The student learns how early man studied the heavens for signs by which he sowed his grain, made his travels, in fact, pursued his everyday life, and also how he employed the phenomena of the skies in his religion and superstitions. Later the student learns about the further development of astronomy in various lands and by means of various instruments.

This leads us to investigate the value of astronomy in life today. We learn how astronomy helps to tell exact time, navigate the ships of the air and sea, and to understand the rise and fall of the tides.

We then examine the solar system as an example of orderliness, thereby touching every part of the solar system including the earth with its seasons.

From this we turn to other orderly systems in the universe. First we are concerned with our own galaxy. Then we travel to other galaxies and also make a more definite study of individual stars and the instruments used in studying them. It is at this point that I always take my 6-inch mirror and the grinding tool to the classroom to help explain the reflecting telescope.

Teachers are allowed a certain latitude in selecting projects, experiments, and demonstrations to teach the information outlined above; for example, some classes make a simple refracting telescope by attaching lens holders to a yardstick, inserting lenses, and adjusting them until they focus. In my classes we have illustrated the phases of the moon by making a moon collar, as was suggested in "The Sky" magazine several years ago. Rarely does a teacher complete this unit without assembling her class for at least one night's observation.

Through it all, the teacher hopes to bring to the pupils an appreciation and understanding of scientific contributions in astronomical fields, to leave a feeling of awe, and to orient the student to the universe in which he lives.

MRS. ELANORA B. DAVIS

*Reprinted from **Star Dust**, January, 1945, published by the National Capital Amateur Astronomers Association.

THIS MONTH'S LECTURES

Cincinnati: At the meeting of the Cincinnati Astronomical Association on Friday evening, February 9th, "Celestial Navigation," a sound motion picture, will be shown, through the courtesy of the U. S. Naval Aids Training Library, Chicago, and the local office of the Navy Public Relations. The meeting is at the Cincinnati Observatory, Observatory Place, at 8:00 p.m.

Detroit: On Sunday, February 11th, at 3:00 p.m., at Wayne University, "The Relation of Physics to Astronomy" will be the subject of a talk before the Detroit Astronomical Society by Gordon Shaw, radio commentator.

Madison: Professor R. C. Emmons will address the Madison Astronomical Society on "Volcanoes," on Wednesday, February 14th, at the Washburn Observatory.

New Haven: The meeting of the New Haven Amateur Astronomical Society, at Yale University Observatory on February 24th, is planned especially for the younger devotees of astronomy, with movies, quizzes, and the like making up the program.

New York: "Meteors" is the title of the talk before the Amateur Astronomers Association on Wednesday, February 7th. The speaker is Dr. Charles P. Olivier, director of the Flower Observatory of the University of Pennsylvania and president of the American Meteor Society. The meeting is at 8:00 p.m. at the Roosevelt Memorial building of the American Museum of Natural History. Guest tickets may be had by calling the society headquarters in the Museum, ENdicott 2-8500.

MIRA AT MAXIMUM

The predicted date of maximum for Mira this season was January 15th, and if we can judge anything by the trend of the light curve to January 1st, when the latest reported observation was made, it looks as if the variable would hold true to form and attain greatest brilliancy on the predicted date. At magnitude 3.5 on January 1st, and slowing up in the rate of its increase in brightness, it seems that the star would not become much, if any brighter than the 3rd magnitude. Mira increased from the 7th to the 4th magnitude in 17 days, about one magnitude each six days.

LEON CAMPBELL

January 12, 1945

The midnight sun arcs over the northern horizon. Photo by Donald B. MacMillan, at Etah, Greenland.

A TRIP AROUND THE WORLD

By Marian Lockwood

A quick north-south journey around the world reveals many facts about earth and sky, as told here and in the Hayden Planetarium this month.

THE man or woman not in the armed forces has, these days, very little chance of exploring for himself the mysterious fascination of such countries as Borneo, Tibet, Turkestan, and the Gold Coast. Civilian travel to foreign lands is a thing almost unheard of. But however homekeeping the civilian heart may be by force of circumstance or inclination, it still beats a little faster at the thought of the strange mysteries which are found in other lands than ours, especially when thought flies to dear ones who are spending their days and nights beneath the skies which shine over these unknown lands.

What, then, could be more fitting than that we, in our planetarium sky ship, should start on a trip around the world—seeing for ourselves not primarily the changing earth speeding along below us, but the strange wonders to be observed in the sky above. For to a man fighting in the tropics, it is not only the unfamiliar country around him, but also the changing heavens above, which make up the environment in which he lives day and night. This fact is attested by the many letters which are written home asking for information about stars and planets as they are seen from different latitudes. Thousands of little books on astronomy and countless star maps have found their way across the curved surface of the earth into the pockets of G.I. Joes who have come to know the stars as friends in the long watches of the night.

On our trip we shall follow the 74th meridian west of Greenwich right up to the north pole, passing northward up through New York State, Canada, Baffin Island, Ellesmere Island, and to the pole. After a short stay at the north pole we shall travel down the 106th meridian east of Greenwich (exactly halfway around the world), crossing the Taimir Peninsula, southward over Siberia, Mongolia, China, Sumatra, the Indian Ocean, on to Antarctica, and the south pole. Coming home from the south pole, our trip will take us northward again along the 74th meridian west of Greenwich across southern Chile, Peru, Colombia, the West Indies, and back to New York.

We have chosen this itinerary, rather than one toward the east or west along a given parallel of latitude, just because we want to see changing skies. If we were to travel on one parallel of latitude, we should always see the same celestial regions. For instance, if a man who is living in New Orleans imagines that his soldier son in Chungking is seeing different stars from those at home, he is mistaken. For these cities are on approximately the same parallel of latitude, and the only difference in the observation of the heavens by the two men is a difference in time. Exactly the same stars and planets would be seen, with the sun and moon in almost exactly the same positions. To see different and new constellations one must change latitude, not longitude.

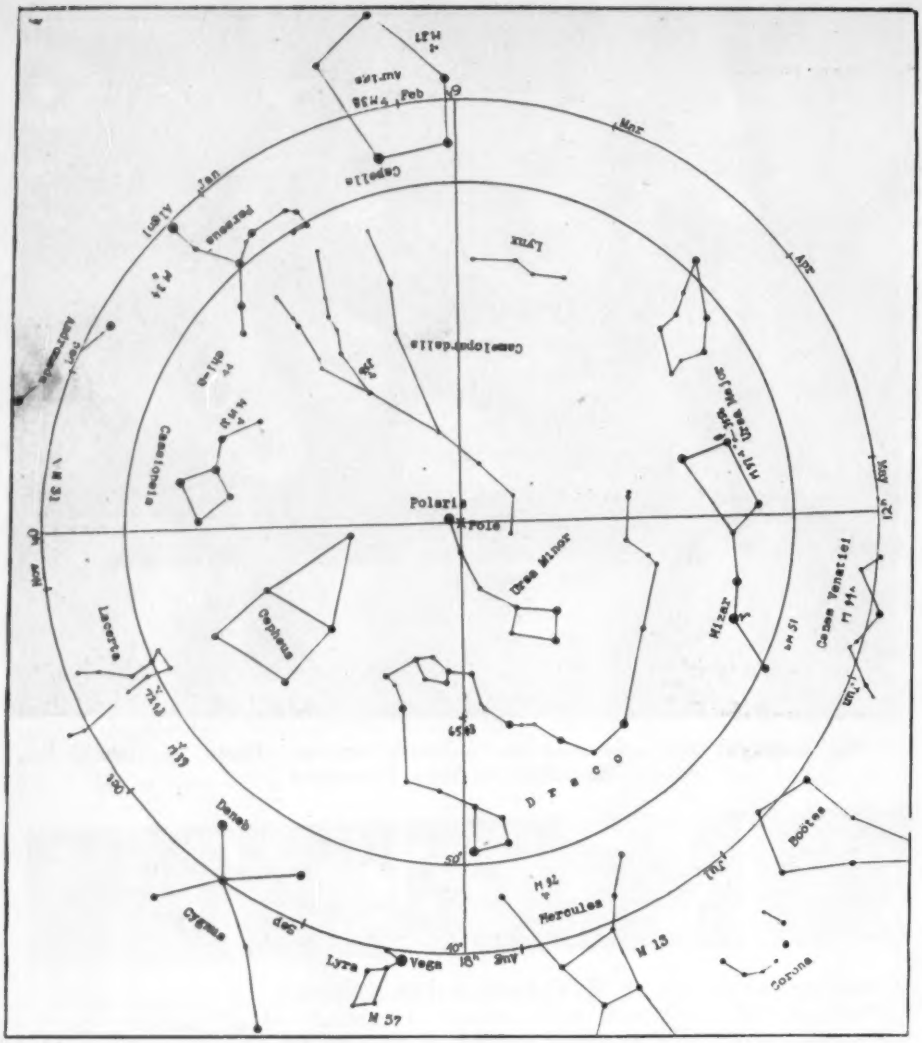
On this journey we shall travel rapidly, more rapidly than explorers have ever traveled both in time and in space, for our plans make it necessary for us to be back home again in less than an hour. We stand on the air field outside New York City enchanted by the twinkling lights of the city and the constellations.

Directly to the south stands the familiar Orion, the most beautiful of our winter constellations, and one which is visible to travelers in both Northern and Southern Hemispheres at this time of the year. The top star of Orion's belt, known as Mintaka, is almost exactly on the celestial equator, which divides the sky into two hemispheres, and therefore, no matter how far north or south you go, you can always see part of this group of stars if you look during the right seasons of the year.

We notice that the stars as seen from this latitude, and indeed from any latitude between the equator and the poles, appear to move across the sky obliquely — they rise obliquely and they set obliquely. For this reason the sky is known in these latitudes as the *oblique sphere*.

Our plane is ready and we start on the first lap of our trip to the north pole. As we rise above the mist and the lights of the city, the stars increase in brilliance and clarity, and we realize perhaps for the first time what astronomers mean by almost perfect seeing. We are traveling just above the surface of the globe of the earth, and as we travel north over that round surface our view of the sky changes.

The northern stars appear to rise while the southern stars seem to be sinking toward the southern horizon. This observation of ours fits in with the first rule of the navigator, namely,



North circumpolar constellations. For evening skies of a given month, hold the chart with that month at the top.

that the altitude of the celestial pole equals the latitude of the place from which you observe it. In New York City the height of the celestial pole is approximately 41 degrees, corresponding to the latitude of New York. When we have traveled north 10 degrees we find that the pole star has risen 10 degrees higher in the heavens. If at the same time we watch some bright star in the south, let's say Betelgeuse, we find that star has sunk 10 degrees toward the southern horizon. This apparent shifting of the celestial sphere, to the north or to the south, depending upon the direction in which one journeys, is one of the best proofs that the earth is round. On a flat surface, we should see the same stars no matter how far we went.

Another interesting observation to make before we leave middle latitudes is that the stars of the northern sky appear to move in a counterclockwise direction around the north celestial pole. Polaris, only one degree from the pole, is easily located on the extension of a line connecting the two pointer stars at the end of the Big Dipper's bowl. From 41° north latitude, the Big Dipper and several other star groups are *circumpolar,* that is, they never set.

As we travel farther north the pole star rises higher and higher until, when we finally reach the north terrestrial pole, the celestial pole is in the zenith with the pole star close to it.

At this time of the year, as we go northward, the days become shorter and the nights longer, until we finally reach a latitude where there are twilight and dawn periods but no actual sunlight in the sky. This is the land which in the summer is known as the land of the midnight sun; then the sun does not sink below the horizon during an entire period of 24 hours or more.

When we reach the pole we shall disembark from our plane for a brief moment of exploration and discovery in this most northerly region of the earth. There are many interesting and strange truths which we shall discover at the pole.

We have arrived at the north pole toward the end of the long polar night —the sun has not been seen here since September 23rd when it disappeared below the horizon. It will rise again about March 21st, approximately a month from now. The statement is sometimes made that the polar night is six months long and the polar day of equal duration. This is not quite true. The sun is actually below the horizon six months here, but the periods of twilight and dawn last for about two months each, leaving only six or seven weeks of totally dark night. Even this period is not one of entire blackness, for during any such length of time the moon will come to the full phase once or twice, giving several weeks of bright moonlight to alleviate the total darkness.

It is interesting to observe that here in the depth of winter (the same is true at the south pole) a thin crescent moon would not be seen, since the crescent moon is always close to the sun and during midwinter the sun is far below the horizon. However, during the period of its greatest brightness, from about first quarter to last quarter, the moon would be visible each month.

Among the "auxiliary" lights in the sky is the not inconsiderable illumination given by the aurora borealis, which is visible a great deal of the time in far northern latitudes. However, to mention only the aurora borealis, or northern lights, tells but a part of the story. Similar sky lights are seen from the Southern Hemisphere, and are called the aurora australis, or southern lights.

The explorer exactly at the north pole has the peculiar experience of always facing the same point of the compass, no matter which way he turns, since from the north pole there is only one direction, south. There is no local time, as there can be no north-south meridian by which to measure it.

Anomalous as it may seem, the north pole experiences the greatest total duration of sunlight during the course of the year. The average person, when asked to name the point on the surface of the earth which receives most sunlight, is very likely to answer, "any place on the equator." The period of summer at the north pole is longer than it is anywhere else, since when it is summer there the earth is farthest from the sun and moving more slowly in its orbit. This makes a difference of about seven days between the length of summer in the Northern Hemisphere and in the Southern.

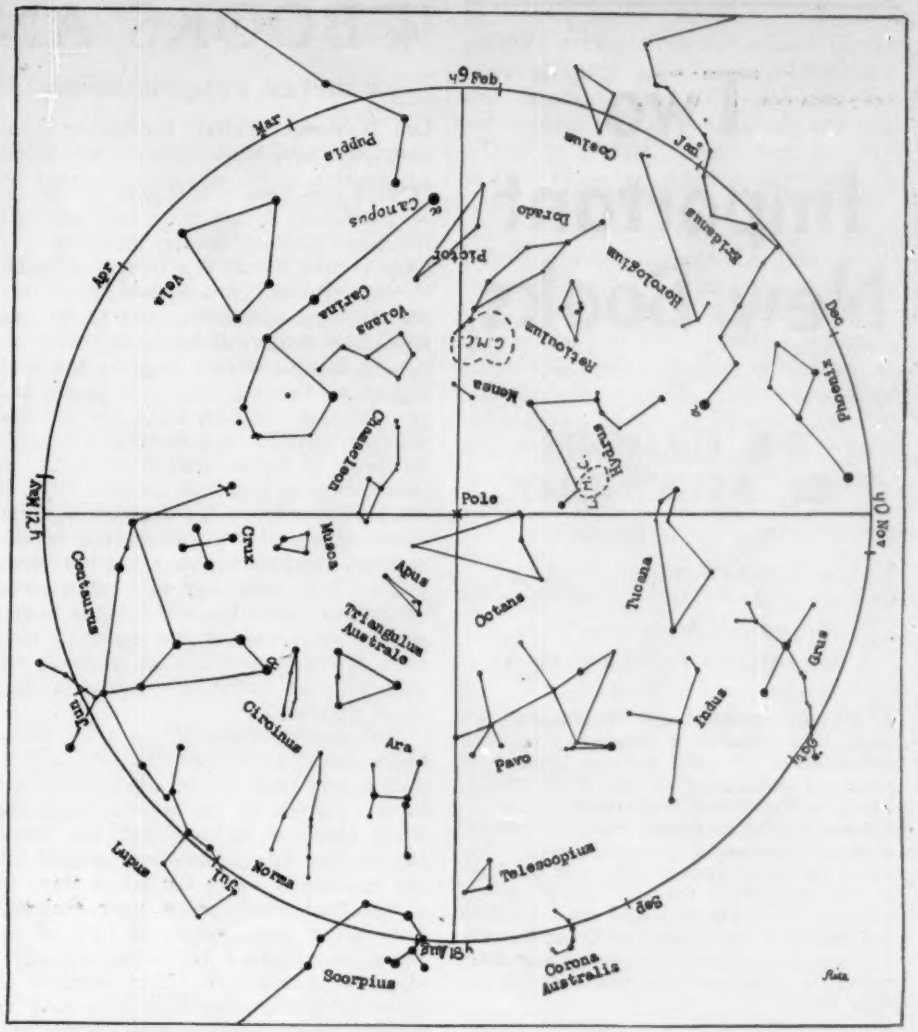
As seen from our position at the pole, all stars are circumpolar, that is,

all the stars which are visible. In the case of the north pole these include all the stars of the northern hemisphere, for the celestial equator is coincident with the horizon line. Also, instead of moving obliquely across the sky, the stars in the polar heavens move in circles parallel to the horizon, and because of this the sky at the poles is called the *parallel sphere*. Since the celestial pole is directly in the zenith for a polar observer, the pole star itself may be seen to describe a small circle around the zenith, a circle about four full moons in diameter, about two degrees.

It is a common misconception that one would weigh the same at any place on the earth. At the poles, actually, one's weight would be about 1/190 greater than at the equator, since at the poles the earth's surface is closer to the center of the earth, or the center of gravity, than at any place along the equator. In other words, the equatorial diameter of the earth is about 27 miles greater than the polar diameter.

But now the time has come to step back into our plane and continue our journey around the world. We now fly down the other side of the world, stopping at the equator for a brief period of inspection. Here we find that the stars are rising and setting perpendicularly, at right angles to the horizon. For this reason the sky at the equator is known as the *right sphere*. Theoretically speaking, the observer at the equator should see the north celestial pole on the northern horizon and the south celestial pole on the southern horizon. If he were to remain on the equator during the entire year, theoretically again, he should by the end of the year have seen all of the naked-eye stars. Day and night are exactly equal at the equator and here dawn and dusk are somewhat shorter than in other latitudes. However, contrary to often quoted statements, there is at least an hour of twilight between day and night and between night and day.

As our plane now travels on toward the south, we notice the southern stars rising and the northern stars setting. As we crossed the equator the North Star sank below the northern horizon and the dim region of the sky in which we find the south pole came above the southern horizon. Traveling so fast, we have the strange experience of passing very quickly from winter in the Northern to summer in the Southern Hemisphere. At this time of the year the south end of the earth's axis points toward the sun, which means that the sun's rays are striking the Southern Hemisphere more directly than they are the Northern. As we proceed farther south of the equator the days become longer and the nights shorter, just the reverse of what we found to be true as we traveled north of the equator. We shall reach the south pole toward the end of the long antarctic day (summer), which began when the sun pushed its way above the horizon on September 23rd. This, you remember, is the date when the sun disappeared at the north pole. Each 24 hours during this polar day of more than six months, the sun has seemed to circle around the sky appearing to keep about the same altitude. In reality it has been spiraling, upward from September 23rd to December 22nd, and downward from then to March 21st, when it will disappear at the beginning of the long south polar night. December 22nd is either noon or midsummer at the south pole, whichever way you choose to look at it. Here, as at the north pole, the stars in the long winter night move parallel to the horizon, and, in general, the same things that were true at the north pole are true here though at the opposite time of the year.



Observation of the south circumpolar constellations must await a journey to mid-southern latitudes.

From the south pole, if we could stay here until the darkness of the polar night had descended, we should be able to see many groups of stars invisible to those of us who live a considerable distance north of the equator. The Southern Cross circles around the south pole very much as our Big Dipper circles around the north pole, and at about the same distance. By drawing a line from the top of the cross through the bottom of it and extending that line about four times we can approximately locate the south celestial pole. As we travel back toward home, northward in the Southern Hemisphere, we notice that the stars move around the south celestial pole in clockwise fashion, the reverse of their apparent motion in the Northern Hemisphere.

As we cross the equator, we realize that we are approaching home once more for the pole star slowly climbs up the northern sky, and the Dipper, the most familiar of all star groups, once more comes into view.

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BOOKS AND THE SKY

A DIPPER FULL OF STARS

Lou Williams. Follett Publishing Company, Chicago, 1944. 170 pages. $2.00.

THIS new book fills a need for an introduction to the stars and star lore for science clubs, scouts, and even for parents who would like to feel at home in the universe. The author has a very smooth style of writing, and mixes just enough of delightful mythology with seriously tackled science to make the book appeal to the dilettante stargazer and the budding scientist alike. For those who don't really care whether the moon is made of green cheese or rocks, it would be wise to avoid the last third of the book, for there the author makes an effort to cover a year's course in elementary astronomy in about 70 short pages. It is done very well (with a few exceptions noted below), but the beginner in astronomy would need to read each sentence carefully in order to digest all the knowledge crammed into these chapters.

The main portion of the book introduces one to the constellations, and in such a way that almost a total stranger to the sky should be able to learn the stars' names if he can locate the direction north. The illustrations in the book are excellently done; the white stars on a blue background seem very realistic. The fainter stars, reference lines of celestial co-ordinates, and confusing mythological figures have been omitted or made so unobtrusive that it is easy to see the bright configuration as you will see it in the heavens. Incidentally, it is wise for a new stargazer to begin on a night with some moonlight or haze, for then the bright configurations stand out without myriads of faint stars to confuse the picture. Of course, the faint constellations cannot then be observed, but one can cement friendship with the bright ones.

There are a few points in the book which bear criticism and a few places where real errors are likely to be misleading. It would certainly not be worthwhile for anyone with a tall chimney available to try to see a few bright stars in the daytime, as suggested on page 15. There is some question as to whether it can be done at all, and it isn't easy to tip a chimney toward Sirius or Vega.

In introducing Leo on page 67, the author forgets that Virgo, another member of the zodiacal group, was presented earlier. The treatment of Virgo on page 29 and the accompanying figure seem very brief and inadequate for such a large constellation, but if one also consults Figure 41, a very good picture of this group can be formed.

It seems unfortunate that on page 70, as throughout the book, it is not mentioned that the Manger is in the constellation of Cancer, the Crab, and is in the zodiac. It is well to know the zodiacal constellations, for then you know where to expect the moon and planets. If you find a bright "star" in this belt that is not on your star maps, you usually check to see if it is a planet before you phone the nearest observatory that you have discovered a nova or a comet!

For an understanding of the reason for the retardation in the rising of the moon on consecutive nights, the explanation on page 140 is inadequate and an additional text should be consulted if you are curious. The treatment of tides is good except for two mistakes; it should be noted that there are not **always** two high and two low tides a day at all parts of the globe. At some places in high latitudes when the moon is far from the celestial equator there is often only one tide a day, or at least one high and one very mediocre tide. On page 143 it is incorrect to say that points A and B are at low tide; they are, of course, at high tide, with their shores passing under the bulge of water.

When reading the interesting account of the double star Algol on page 41, keep in mind that the companion of Algol is not visible to us since the system is so far away and compact that it looks like a single star; we learn of the presence of the companion by the way it affects the light of the system.

The phases of the moon puzzle many beginners. Figure 76 is a meritorious but unfortunately quite misleading attempt to simplify this phenomenon. Furthermore, the alert student will be more puzzled than the casual reader by such a thing as the rays of the sun appearing to shine on us from the same direction as the earth goes around its orbit. The moon completes one revolution in about 1/13 of a year, but here it moves with the earth more than one sixth of the way around the sun in a month. The second new moon is shown at the end of a sidereal instead of a synodic revolution.

Also, in this same figure, the earth and moon have identical sizes, but this may make the diagram more readable. When the moon is eclipsed, however, it is small enough and near enough to the earth to remain in the earth's shadow for an hour or more, and not just barely to pass in and out again, as shown in Figure 80; here relative size is particularly important.

If you keep these few corrections in mind, it will be well worth your while to read **A Dipper Full of Stars**, which is, on the whole, a very delightful and intelligent introduction to stargazing.

EDITH JONES WOODWARD
Harvard College Observatory

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ASTRONOMICAL ANECDOTES

ARBITRARY BEGINNINGS

I'VE run across one or two interesting ideas lately, in culling over many references to calendars and such things. Most of us know that Dionysius Exiguus (Denys the Little), always described as a Scythian monk and the abbot of Rome, established the idea of the Christian Era. The year was what we now call 533 A.D., and I have often wondered why it was that Dionysius ignored the evidence of Flavius Josephus, in the matter of the death of Herod, and why, if he was a capable researcher, he could have made the mistake of misdating the time of the accession of Caesar Augustus.

In *The Antiquities of the Jews*, Josephus describes the death of Herod as having taken place not long after an eclipse of the moon which many scholars have identified with that of March 13, of 4 B.C. Obviously, then, if this is true, Jesus must have been born before that time. Surely this and other information must have been available to Josephus, yet he stated that the year 1 A.D., the year following the birth of Jesus, had occurred 532 years before his own time, and we have counted ahead since that time, although for several centuries we have known that there is an error of between four and eight years.

Victorius, the bishop of Aquitaine, discovered that Easter dates repeat themselves exactly in a period of 532 years, for the dates of the Sundays repeat in 28 years and the dates of the lunar phases in a period of 19 years (the cycle of Meton). This Victorian period of 532 years was announced, then, in the same year Dionysius Exiguus decided that the year 1 A.D. had occurred exactly 532 years earlier! This is a remarkable coincidence! To my mind, it is an indication that Dionysius did his best to determine the date of the birth of Jesus, but, finding the task to be a trifle confused, he somewhat arbitrarily seized upon the number 532 and put it to his use.

Without turning into some kind of hermitic bibliophile, it is difficult to investigate all these interesting matters. Occasionally such a coincidence will be noticed, however, and carelessly published as personal opinion (as in the paragraph above), then perpetuated as fact. I hope that some of my readers who have access to more and better facts than mine will put me straight, if what I have set down is preposterous. And now, here's another.

In writing some things about the calendar for the general reader, I recently attempted to explain the notion of a lunar calendar and why it was unsatisfactory. Quite without special design, I wrote something like this: "Suppose a primitive farmer noticed that one spring, as he planted, there was a full moon; months later there came the harvest, then the winter, then the beginnings of another spring. Again when the ground was right and the weather seemed good, he planted at a time of a full moon, because he had resolved to use the moon as his long-scale timekeeper. This time perhaps his harvest was also good, despite his gain of 11 days because 12 lunations add up to only 354 days. . . ." And so I wrote on, to show how, eventually, an extra month would need to be inserted in the calendar.

Could this sort of thing be the origin of the many moon superstitions among farmers? Agriculture began in the days of the lunar calendar, and perhaps some of the old notions have persisted, not because planting in certain phases of the moon had ever given exceptional results, but because certain phases of the moon had been chosen in the very earliest times to mark the beginnings of the years.

The origins of astrology have never been sufficiently explained to me. I have been forced to make up my own theory which, to my mind, is at least an idea of how astrology *may* have been invented. The Babylonians, or peoples earlier than them, saw in the heavens seven objects whose positions are constantly variable: the sun, the moon, and the five naked-eye planets, Mercury, Venus, Mars, Jupiter, Saturn. These seven bodies moved, hence were set apart from the other stars. Five of them behaved in strange ways, moving eastward, then westward, sometimes slowly, sometimes rapidly. Their motions were not easily reduced to rules and regulations; with the earth assumed as center of the universe, good explanations were not likely to be formulated by the Babylonians. The unruly celestial bodies were considered as behaving according to whim, not conforming to rule. But only the gods could be so whimsical, so the names of the principal gods were given to these moving bodies. Later the powers of the gods were also transferred to the planets and, since the gods ruled mankind, the planets must rule mankind. If the origins of astrology were as silly as this, we have a potent argument for combating belief in it.

In a local newspaper, there appeared this paragraph in a by-lined column: "A noted astrologer sent a forecast for 1944, under date Dec. 31, 1943, which was filed away for future reference. It prophesied the defeat and elimination of Germany from the war before May 22, 1944, and an attempt by Japan, about that time, to negotiate peace terms with U.S. It predicted conflict between England and Russia before the fourth month of 1944. It opined that Japan would be virtually wiped off the face of the earth before November, 1944, if her peace attempts failed. So-o-o-o?"

This is the sort of thing that should be done more often. But there is a somewhat jarring note when we find, on the opposite page of the same newspaper, *Planetary Guide for Monday, January 1, 1945*, a daily feature of that newspaper! R.K.M.

OCCULTATIONS—FEBRUARY, 1945

Local station, lat. 40° 48'.6 north, long. 4h 55m.8 west.

Date	Mag.	Name	Immersion	P.*	Emersion	P.*
Feb. 6	4.3	Theta Librae	5:52.7 a.m.	61°	6:47.0 a.m.	350°
14	6.8	BD —6° 6335	8:16.6 p.m.	112°		
17	6.7	BD +9° 353	7:12.9 p.m.	20°		
19	Var.	BD +18° 661	9:04.3 p.m.	78°		
20	6.1	302 B Tauri	1:45.1 a.m.	107°	2:35.9 a.m.	242°
20	6.8	BD +20° 969	6:35.9 p.m.	103°		
20	3.0	Zeta Tauri	11:25.2 p.m.	30°	0:12.0 a.m. (21)	326°
22	6.3	BD +22° 1416	1:51.1 a.m.	42°	2:33.0 a.m.	331°
23	5.9	49 B Cancri	8:06.0 p.m.	27°	8:45.7 p.m.	343°

*P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

The INDEX for Volume III

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OBSERVER'S PAGE

By Jesse A. Fitzpatrick

All times mentioned on the Observer's Page are Eastern war time.

The Superiority of Large Telescopes for Visual Lunar and Planetary Observations

THE question of whether large or small telescopes show to best advantage the detail on the surfaces of the moon and planets has caused much controversy in the past. W. H. Pickering has argued that in 1924 better views of Mars were obtained with small apertures than with ones exceeding 20 inches[1]. Denning has discussed the performances of various instruments at some length; his conclusions apparently are that the optimum aperture for planetary work is about 15 inches and that views in smaller telescopes are usually as good or better than in those exceeding this size[2]. Lowell considered it advantageous to diaphragm a 24-inch telescope to 18 inches, and even to 12 inches, as is well known. On the other hand, Antoniadi has concluded that planetary surfaces are seen much better in large instruments than in ordinary or small ones[3]. Hale has praised the "exquisite structure" of delicate lunar features as seen with the largest instruments[4]. Additional conclusions of well-known observers, sometimes favoring small apertures and sometimes large, could be cited.

In view of these wide differences of opinion, I should like to report my own experiences. Between 1935 and 1941, I conducted regular visual lunar and planetary observations with a number of different telescopes, both reflectors and refractors, ranging from four to 12 inches in aperture. Some of these instruments were of unusually good quality. From 1941 to the present, I have made some such observations with the 18-inch Brashear refractor at the Flower Observatory. This instrument has supplied much better views than those previously obtained with smaller telescopes, even though it is severely handicapped by the adverse atmospheric conditions at its location in suburban Philadelphia.

More exactly, it has not shown Mercury and Venus any better. I think that with Mercury, the invariably very poor conditions of observation harm the definition more in the large telescope so that nothing is gained, and that on the very brilliant Venus, where glare is a serious problem even with small telescopes, the increased brightness of the image in the 18-inch lessens the already very slight contrasts so that detail becomes still more difficult. To infer that many other large telescopes are comparably good for lunar and planetary views appears permissible.

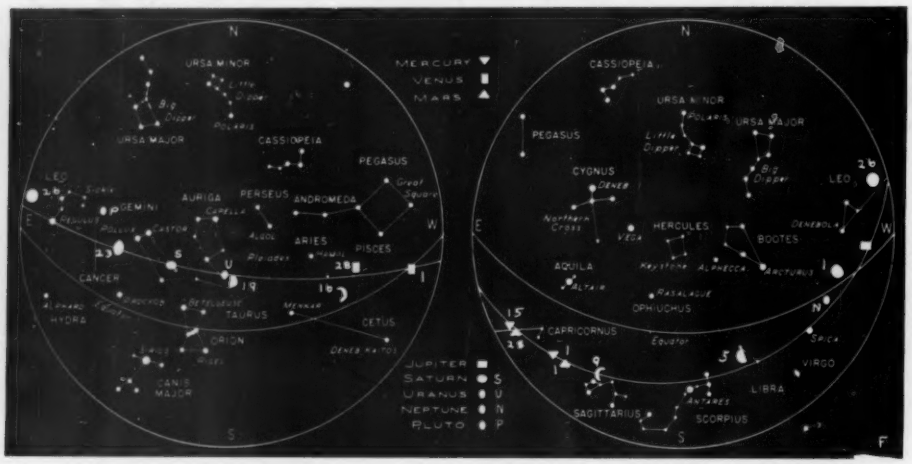
The accompanying reproduction of a drawing of Saturn will illustrate my argument to whatever extent the engraving retains the fainter details and contrasts present in the original drawing. The planet is shown as I saw it near 9:23 p.m. E.W.T., on January 7, 1944, with 300x on the 18-inch—the sky was clear and the seeing was poor to fair. I have discussed the Saturnian system elsewhere recently[5]. A number of features not usually imputed to this system and not easily visible in most ordinary-sized telescopes are drawn here. Encke's division has often escaped skilled observers using good telescopes[2, 6], but the Flower refractor usually reveals it clearly. The division (or shading) near the inner edge of ring B is similarly regularly visible. The division between rings B and C is more difficult. This telescope shows ring A to be brighter outside Encke's division than just inside it and ring B similarly to be brightest in its outer portions. The thin, bright annulus just outside Cassini's division has been seen frequently. The division (or shading) near the outer part of ring B is very delicate and is seldom seen distinctly.

On the ball of the planet itself, the two faintest belts would probably have escaped observers using small telescopes. It will be noticed that there were seen several marks on the ball suitable for transit work designed to reveal rotation periods[7]. I observed 382 such transits during the 1943-44 apparition of the planet; 200 more were obtained in August-November, 1944, but I have not analyzed the observations with sufficient precision to publish final results. Preliminary studies, however, suggest a period of about $10^h\ 17^m$ for marks at the north edge of the main belt; about $10^h\ 20^m$ for marks at the south edge of this belt; and about $10^h\ 7^m$ for marks in the faint belt close to the Saturnian equator. The provisional character of these figures must be emphasized.

Some other difficult observations manifest the superiority of the 18-inch for lunar and planetary observations. Jupiter II has twice been seen as a darkish spot in transit near the center of its primary. The phased outline of Jupiter and the cusps of that planet have been observed near quadrature. The close "canals" on the northwest inner wall of the lunar crater Aristillus[8, 9] have been divided when conditions were favorable.

Theoretical advantages of large aper-

THE MOON AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 8:30 a.m. on the 7th of the month, and at 7:30 a.m. on the 23rd. At the left is the sky for 8:30 p.m. on the 7th and for 7:30 p.m. on the 23rd. The moon's position is given for certain dates by symbols which show roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury is too near the sun for observation.

Venus, in Pisces, will be at magnitude —4.2 by the end of the month. It will be at greatest elongation east of the sun, 46° 52′, on February 2nd, setting more than four hours after the sun.

Mars, in Sagittarius and Capricornus, is inconspicuous in the morning twilight.

Jupiter is in Virgo, and reaches magnitude —2.0 at the end of the month. It will be 50′ north of Beta Virginis on the 12th.

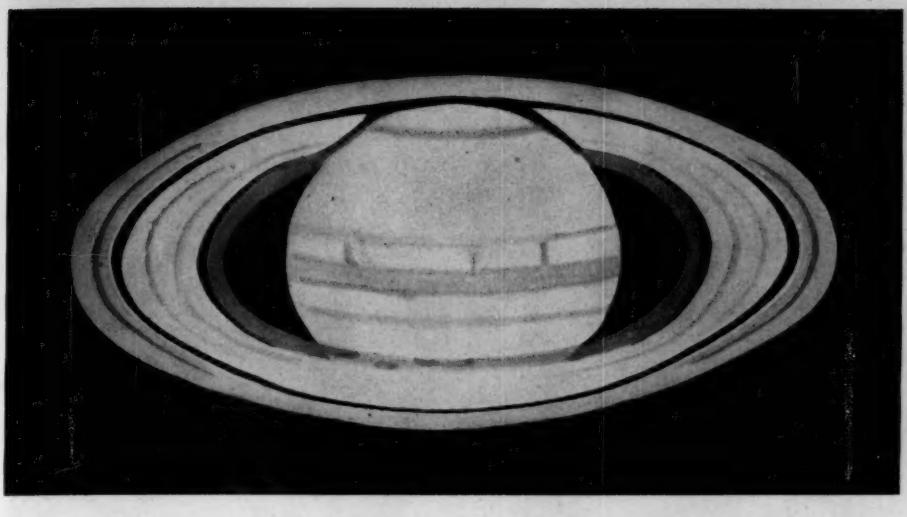
Saturn is conspicuous in Gemini, visible throughout the evening hours. Its conjunction with the moon on the 21st will hold no special interest for observers in northern latitudes.

Uranus will cease its retrograde motion on the 15th of the month. It is in Taurus; see diagram last month.

Neptune. See diagram last month.

PHASES OF THE MOON

Last quarter ...February 5, 5:55 a.m.
New moon .....February 12, 1:33 p.m.
First quarter ...February 19, 4:38 a.m.
Full moon .....February 26, 8:07 p.m.



tures on the moon and the planets are fairly obvious. Greater resolving power gives more nearly correct impressions of the aspect of the features; for example, in 1941 and 1942, the 18-inch showed internal detail in a notable south tropical disturbance on Jupiter where other observers with smaller instruments discerned only a solid mass.

At least as important in my opinion is the fact that large instruments give a brighter image and hence one with greater degrees of contrast so that faint features become more easily visible (for example, vague Jovian belts). It is true that some eminent lunar and planetary observers have contended that these theoretical advantages are more than offset by the poor seeing usually prevailing at most stations, for the larger apertures are admittedly more handicapped by disturbed air. Certainly, the larger instruments fall farther short of what they are optically capable of doing than do the smaller ones. My studied opinion is, however, that, at least for apertures up to 20 inches, even in a climate as poor as that of our northeastern states, the theoretical advantages outweigh the handicap of bad atmospheric conditions on most nights, and that one hence should use as large a telescope as possible for lunar and planetary observations.

WALTER H. HAAS
110 N. Madison St.
Upper Darby, Pa.

EDITOR'S NOTE: Next month we shall publish an article by E. K. White, of Chapman Camp, B. C., Canada, telling of his observations of Saturn with a 9-inch reflector.

[1]W. H. Pickering, "Report on Mars, No. 35," *P.A., 34,* 289, 1926.
[2]W. F. Denning, *Telescopic Work for Starlight Evenings,* 1891.
[3]E. M. Antoniadi, *La Planete Mars,* 1930.
[4]G. E. Hale, "Lunar Photography with the Hooker Telescope," *P.A.S.P., 32,* 112, 1920.
[5]W. H. Haas, "Observations of Saturn, 1939-1943," *J.R.A.S.C., 38,* 177, 1944.
[6]P. H. Hepburn, "Saturn," *Splendour of the Heavens,* Vol. 1, 1923.
[7]H. M. Johnson and W. H. Haas, "The 1939-40 Apparition of Jupiter," *J.R.A.S.C., 35,* 53, 1941.
[8]W. H. Pickering, "The Double Canals of the Lunar Crater Aristillus," *P.A., 22,* 570, 1914.
[9]W. H. Pickering, "The Aristillus Test for Planetary Definition," *P.A., 24,* 273, 1916.

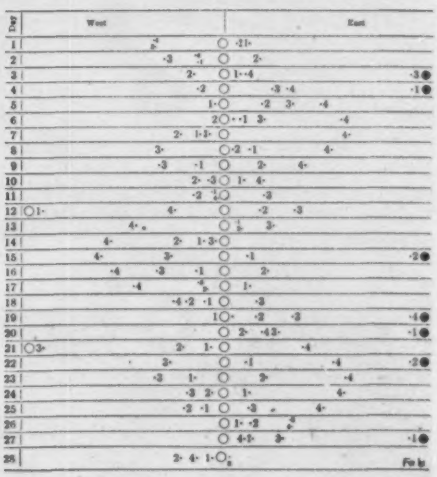
FEBRUARY OCCULTATIONS
Table on page 15.

JUPITER'S SATELLITES

On February 5th and 25th, the four principal moons will be east of the primary before midnight. On the 14th, they will be west of Jupiter after 1:51 a.m.; and on the 28th prior to 9:22 p.m., they will be west and in numerical order outward from Jupiter.

On February 13th, the shadow of III, the shadow that is most easily seen in small instruments, will be in transit across Jupiter's disk from the time the planet rises until the shadow's emergence at 11:28 p.m.

Jupiter's four bright moons have the positions shown below at 5:30 a.m., E.W.T. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, and eclipses and occultations by black disks at the right. From the **American Ephemeris and Nautical Almanac.**



MINIMA OF ALGOL

Feb. 1, 6:02 p.m.; 13, 5:20 a.m.; 16, 2:09 a.m.; 18, 10:58 p.m.; 21, 7:48 p.m.

★ ★

PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents in *February,* THE EARTH AMONG THE STARS.

The fact that we live upon a global earth surrounded by the star-studded sphere of the heavens is one of basic importance to present-day navigators and to all who would understand the new global geography of tomorrow's air age. The theme of this sky show is the relation between our planet and the stars, with particular emphasis on how the navigator guides his craft from place to place by means of the heavenly bodies. Included is a flying trip around the world, to see the sky's changing appearance on such a journey.

★ **THE HAYDEN PLANETARIUM** presents in *February,* A TRIP AROUND THE WORLD. (See page 12.)

In *March,* OUR NEIGHBORS THE PLANETS. Do you know what astronomers think about the possibility of life on other worlds than our own? Do you know how to tell a planet from a star? What are the evening and morning stars at the present time? Why are planets called "wanderers"? What are the rings of Saturn? Why is Mars red? Do you know the answers to these questions about our nearest neighbors in space? During March, the Hayden Planetarium presents the great cosmic drama of the "moving stars" or planets, as they parade through the zodiacal belt, each taking its own time in its own way.

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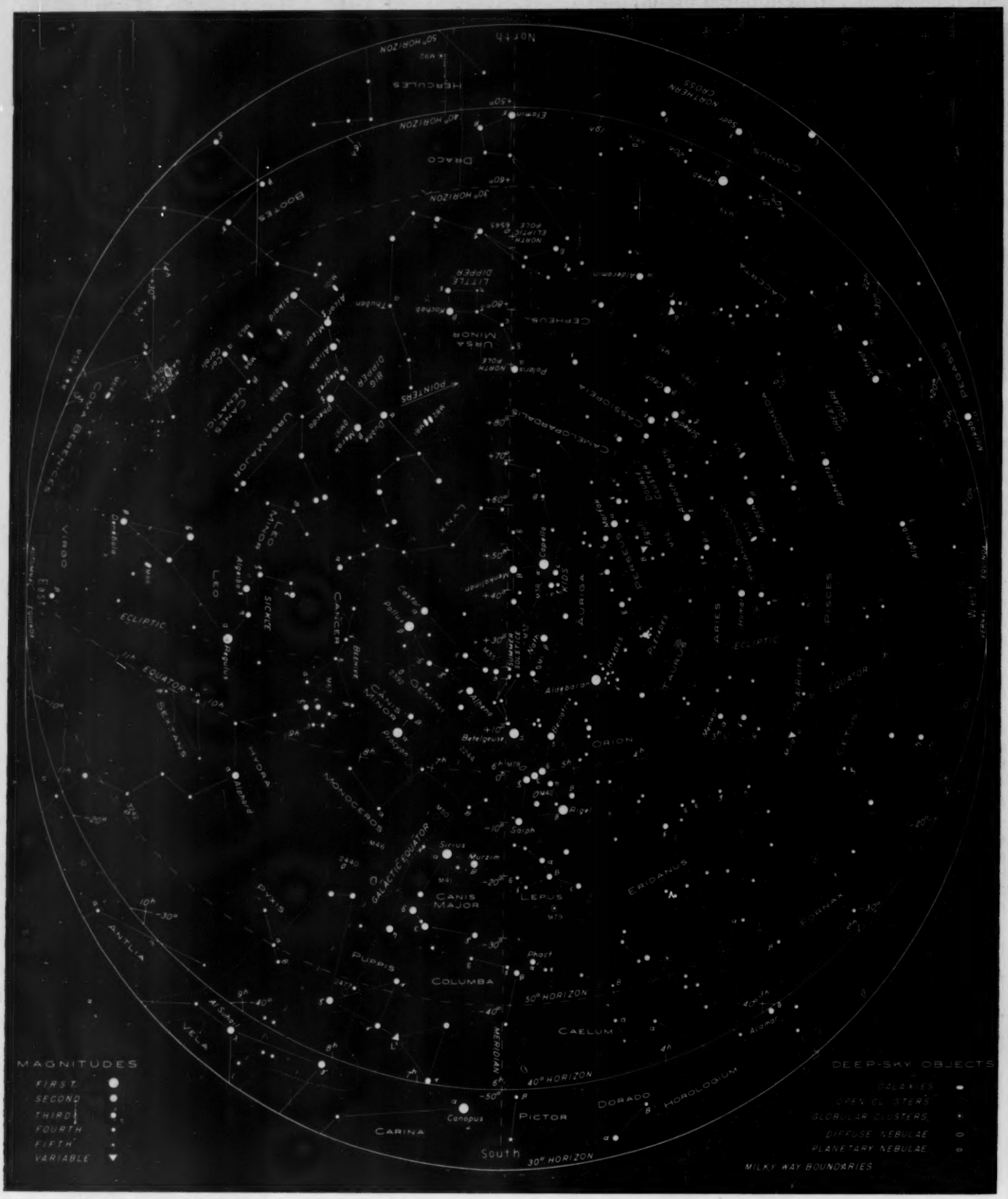
Sundays and Holidays	2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator,* Clyde Fisher; *Associate Curator,* Marian Lockwood; *Assistant Curator,* Robert R. Coles (on leave in Army Air Corps); *Scientific Assistant,* Fred Raiser; *Lecturers,* Charles O. Roth, Jr., Shirley I. Gale, John Saunders.



DEEP-SKY WONDERS

AMONG marvels for observation in the February skies are the objects listed here. The informal descriptions give appearance in common telescopes. Norton designations are in parentheses.

Puppis. M46, $7^h\ 37^m.2$, —14° 35′; a cluster of 150 stars. NGC 2477, $7^h\ 48^m.7$, —38° 17′; a beautiful cluster of 300 stars, which suggests M37, a rich cluster in Auriga.

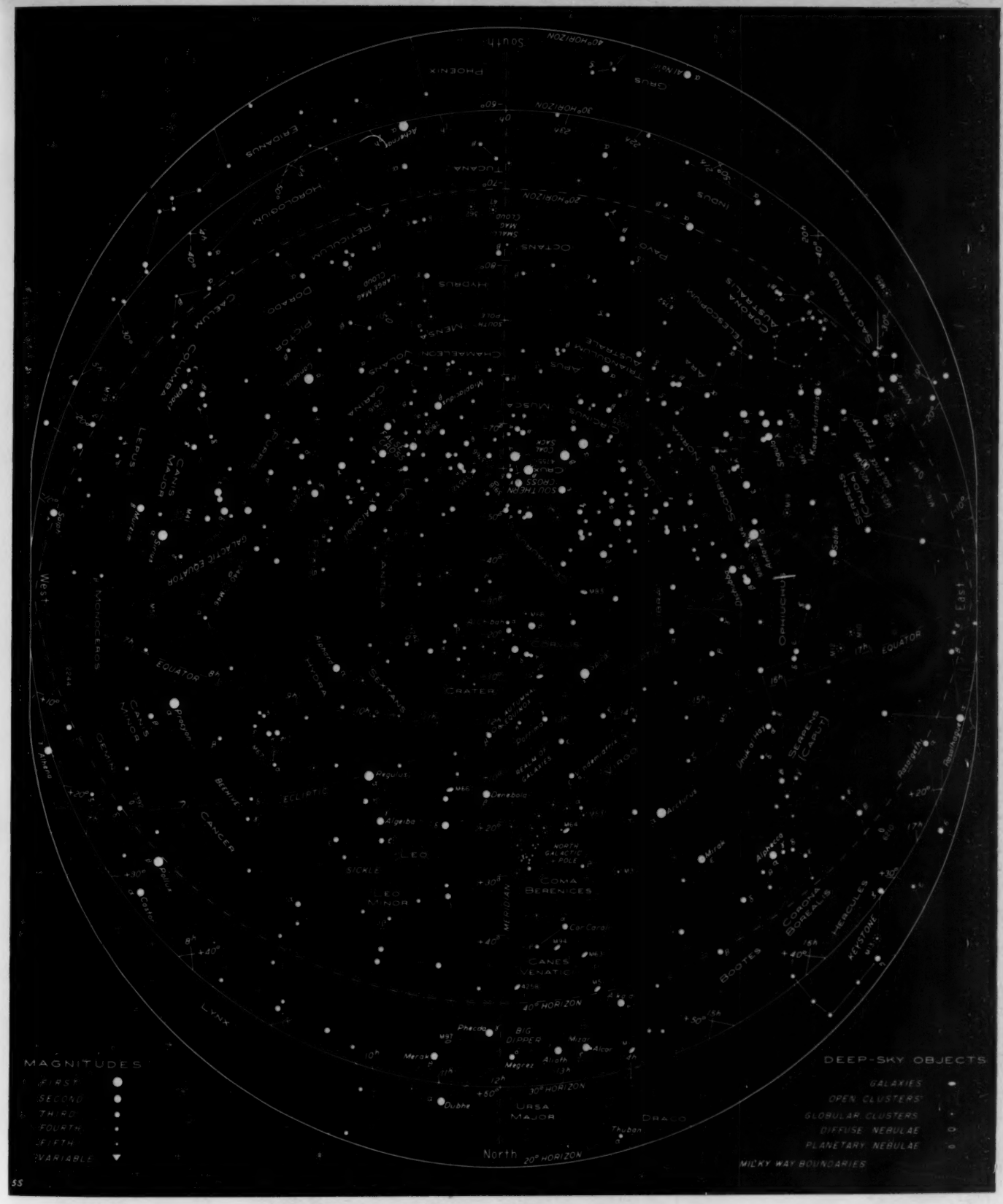
Leo. M96, $10^h\ 44^m.2$, +12° 05′; a dim, oval galaxy, near and following M95, another oval galaxy, one magnitude dimmer.

Canes Venatici. M51, $13^h\ 27^m.8$, +47° 27′; the Whirlpool, a twin galaxy. The first galaxy in which spiral form was observed; situated near the end of the handle of the Big Dipper.

Andromeda. NGC 7662 (18^4), $23^h\ 23^m$, +42° 14′; a planetary, like a light blue snowball when viewed through large amateur telescopes. L. S. COPELAND

STARS FOR FEBRUARY

from latitudes 30° to 50° north, at 10 p.m. and 9 p.m., war time, on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.



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MAKING YOUR OWN TELESCOPE

From Start to Finish—4

By ALLYN J. THOMPSON

V — POLISHING — TESTING — CORRECTING

Polishing Procedure. Before beginning the polishing, the lap and mirror should have been pressed into contact, and made to conform at every point. Wax-coated laps sometimes undergo a breaking-in period, causing the mirror to slip and grab alternately. Thickening the rouge mixture will help to relieve this, although it is desirable to work with as thin a mixture as possible. The lap should be clearly visible through the mirror if a proper mix is being used. Use a one-third stroke, center over center, which can be varied with a W stroke, carrying the edges of the mirror out to an overhang of about ½" on each side of the lap. No pressure other than the weight of the hands should be used. When the lap is in good contact there will be a perceptible drag on the mirror, and some effort may be required to push it around. Work at the rate of 30 to 40 strokes a minute. Frequent rotation of the mirror is not necessary, and never rotate it during the stroke, as this excessive edge action will cause the edge to be turned down. Take six or eight strokes from one position, move around the barrel and repeat the strokes, then rotate the mirror.

After 20 minutes of polishing, wipe the mirror clean with a soft cloth or absorbent tissue, and observe the results. The usual effect of the channeled lap on a spherical mirror is to polish more quickly at the center. A more even polishing goes on with the molded lap. Imperfect contact may cause zonal polishing. A hyperbolic mirror will polish most rapidly at the edge, in which case the stroke should be lengthened just enough to get the lap hitting in the center. This will also reduce the hyperbola. If the polishing falls off abruptly before reaching the edge, it indicates a flattened, or turned-down edge from improper grinding. If, after another period on the lap, the edge refuses to polish, a return to #220 Carbo with the mirror on top will be necessary.

Preliminary Testing. As soon as the mirror is sufficiently polished to give a reflection, usually after about a half hour of work, we will want to examine it on the Foucault stand to see if we can determine its figure. Pick up the sharply focused image of the lamp window on the ground glass as was done with the wet mirror during the grinding stages. By adjusting the mirror rack, bring the reflection to a position like that in Fig. 6, and substitute the knife edge for the ground glass. Sit down with the eye about a foot back of the knife edge and find the reflection of the window on the mirror. Now reach out and slide the pinhole band down over the window so that the large pinhole opening is now before it. Find its reflection on the mirror, then bring the head slowly forward, at the same time keeping the pinhole reflection in view. It will be seen to expand until, with the eye about 1" back of the knife edge, it completely fills the mirror, which appears brilliantly lighted. Now push the knife edge across until it begins to cause a shadow to fall on the mirror.

As we are not going to make zonal measurements yet, the knife edge need not bear against the guide cleat during these preliminary tests. The separation of the pinhole and the knife edge should not be great, however. Theory tells us that if they are at unequal distances from the mirror, an error is introduced in the r^2/R formula for the parabola, and if they are widely separated from the axis of the mirror, distortion is introduced. But within a range of a few inches either way no measurable error can be observed.

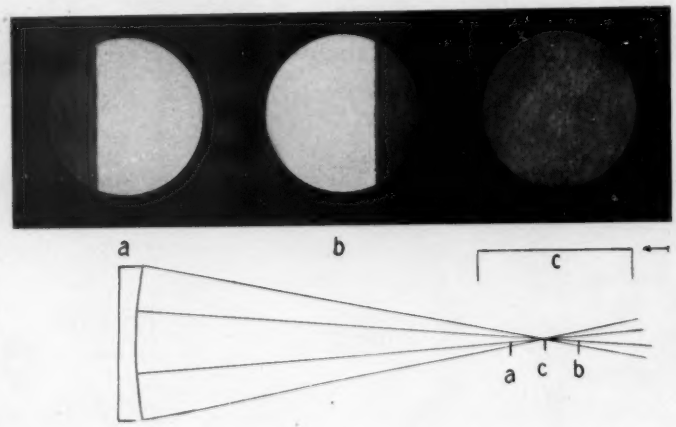

Fig. 14. Knife-edge shadows on spherical mirror.
a. Inside center of curvature; shadow comes in from left, in same direction as the knife edge.
b. Outside center of curvature; shadow comes in from right, opposite to motion of knife edge.
c. At center of curvature; shadow covers entire mirror instantly and evenly.

Now push the knife edge across laterally until it cuts into the illumination from the mirror. Let us suppose it is in the position of a, Fig. 14. Here, it is inside center of curvature, and the

first rays to be cut off are those coming from the left edge of the mirror, so this part of it will darken first, the shadow advancing across the mirror in the same direction as the knife edge moves. Now draw the knife edge back from the mirror about ½" to position b. Here, it is beyond center of curvature and the first rays to be intercepted come from the right side of the mirror, so the shadow starts there and advances in a direction opposite to that of the knife edge. We have now "bracketed the target," as artillerymen say, and the center of curvature c is somewhere between these two settings. We finally locate it and if the mirror is spherical, it darkens evenly and instantly all over when the knife edge is cut in, and we can detect no direction of shadow approach. Even with an unduly large pinhole, this condition would still hold. In that case, as the knife edge moved across the "cylinder" of light, gradually cutting it off, the illumination from the mirror would appear to diminish until the point was reached where the light was completely cut off, when the mirror would darken all over as before.

We can hardly expect to find a spherical surface at this stage, and instead of all of the reflected rays intersecting at c, there is a scattering of intersecting zonal rays along a small length of the axis. Here some parts of the mirror will remain light while others are in shadow. With a very large pinhole, small zonal errors with their faint shadings might not be apparent in the broad transition from light to shadow, so small pinholes are more sensitive. It will be difficult to control the knife-edge movement at this critical juncture, so if we arrest it as it is about to cut into the illumination, and apply gentle downward pressure with the fingers at the right side of the baseboard (Fig. 6), we can probably control this nicely. If

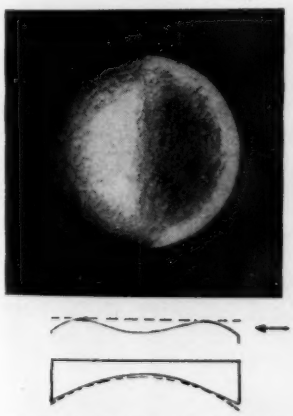

Fig. 16. Hyperboloid. Dotted curve in lower diagram is part of reference sphere at center of which knife edge is placed.

pressing here is too lively, apply the pressure to the top of the bench or stand. Always press at the same spot.

In interpreting the shadows which we see on the mirror, we may imagine ourselves in an observation balloon, viewing a **small section** of the earth's surface (the mirror) which may be a plain, a hill, crater, or any combination of these contours, illuminated by the grazing rays of the sun, rising in the east (or over to the right). In this way a sphere, evenly gray in appearance, would resemble the plain. Even without the exercise of any imagination, a sphere does, in fact, look as flat as the proverbial pancake. See Fig. 14c, showing knife-edge setting, shadowgraph, and apparent cross section of the surface.

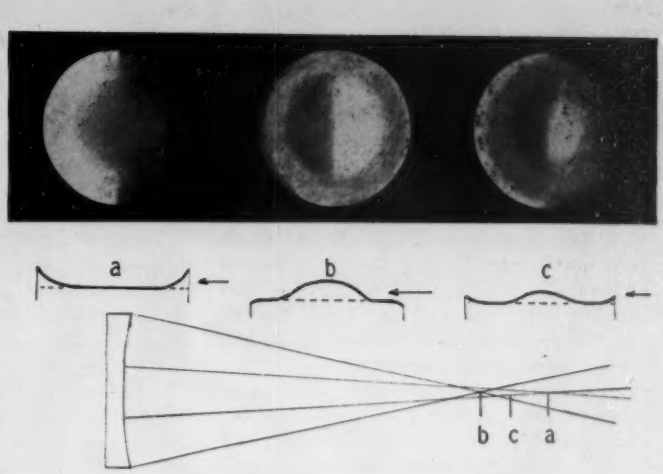

Fig. 15. Knife-edge shadows on oblate spheroid.
a. At center of curvature of edge zone.
b. At center of curvature of center zone.
c. At an intermediate zone setting.
Apparent cross sections of the mirror at each setting are shown under the shadowgrams. Arrows indicate direction of imaginary rays presumed to cause the lights and shadows.

An oblate spheroid, with its center zone of longer radius, is shown in Fig. 15. The figure is made apparent by the hill seen on the mirror. The slope facing the imaginary sun is illuminated, and the opposite slope is in shadow. The surrounding plain is gray, and flat in appearance, because the knife edge is at the center of curvature of that zone. Note the apparent cross section of the surface.

We will find that different knife-edge settings will produce different shadows, and different apparent cross sections of the same mirror. These shadows and shapes are referred to that zone which has the knife edge at its center of curvature. Zones having a longer radius seem elevated, like hills; zones having a shorter radius appear as depressions, or craters. Fig. 15, for example, shows the shadows and apparent cross sections of an oblate spheroid when the knife edge is placed respectively at the center of curvature of the center zone a, edge zone b, and an intermediate zone c.

Fig. 16 shows how the shadows appear on a hyperbolic mirror, in which the center zone is of a shorter radius than the edge. The student should draw a diagram of the rays from this mirror, showing the knife-edge setting that will produce these shadows.

Further Polishing. One may well be a little slow in comprehending all this, but no matter; get back on the lap and continue with the polishing. We can dwell on the whys and wherefores of shapes and shadows while we are walking around the barrel. The chief concern of the moment is to polish out the mirror completely, which may take from three to six hours, depending on the thoroughness of the fine grinding. Cerium oxide is supplanting rouge for polishing optical surfaces. Somewhat more expensive, it is less messy, and gives a beautiful, sleek-free polish in less than half the customary time. The rouge mixture should be thinned so that on looking through the overhanging part of the mirror at the end of a stroke only a faint reddish tinge is vis-

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ible. Renew the charge every 20 minutes or so, or as often as is necessary to forestall evaporation. The rouge particles polish almost indefinitely so at times only water need be added.

After working a half hour give the lap a rest. Center the mirror on it, lay a board on top, and place a weight of a few pounds on that. If too much heat gets into it, the lap will soften and cause trouble. On account of the friction drag, the soft lap tends to follow the mirror as it passes back and forth, causing an excessive deepening of the center. This results in a hyperbolic mirror. A turned-down edge may also result from plowing into the soft pitch. From the many periods of polishing and pressing, the pitch will have sunk down, flowing into the channels and out over the edge of the tool, so an occasional trimming is in order. The lap may be kept as much as 1/16" less in diameter than the mirror as a safeguard against turning the edge. Don't trim it too small or a turned-up edge may result.

Examining for Pits. Pits are apparent in the early stages of polishing by the grayish appearance of the surface, especially at the edges. This grayness is the diffused reflection from the myriads of tiny pits left by the emery. As polishing progresses it disappears, until the surface appears to be fully polished. But do not be deceived by this first impression. On the silvered or aluminized mirror the all-but-invisible pits would stand out in disastrous prominence. With a reading glass, focus the image of the sun or any bright light on the mirror's surface. If any pits are present the "burning spot" will be clearly visible. It can barely be seen on a fully polished surface. Compare its appearance first at the center, then near the edge of the mirror.

Or hold the mirror so that the reflection of an overhead light is seen on its surface, near the edge. Draw it up close to the eye, keeping the reflection in view, and place the magnifier before the eye. Scan the surface of the mirror at the edge, in the vicinity of the light reflection and the pits can be seen, if there are any, looking like a very fine powdering of dust particles. Polishing should continue until they are no longer visible. If necessary, the stroke should be shortened to facilitate the edge polishing.

Correcting. Under the Foucault test the figure on the mirror will probably be some form of oblate spheroid, with a turned-down edge. This is because, under the work of fast polishing, the lap has sunk more at the center, and the edge of the mirror has been riding into a higher level of pitch. If the mirror is hyperbolic, either the lap is too soft, or the stroke used was too long. We first consider the edge.

Turned-down Edge. This is a narrow zone, usually about ⅛" or less in width, but sometimes as much as ½", around the mirror, in which the radius of curvature is rapidly lengthening. It is somewhat like the run-down heel of a shoe. It throws the reflected rays well down the axis, beyond the mirror's focus, and if left uncorrected, in the finished telescope these scattered rays would fall directly into the eyepiece, fogging up the field of view.

There will always be a diffraction ring around the right edge of the mirror, very brilliant if the edge is badly turned. In that case there will be none around the left edge. If the edge is perfect, there will be a fine continuous hairline of light entirely surrounding it, of nearly equal brightness on both sides. The ring on the right should not persist beyond the point where the mirror is completely blacked out as the knife edge is cut across.

To correct turned-down edge, the first thing to do is to overhaul the lap. The wax coating is pretty well charged up with glass, so scrape it off. Clean out the channels and trim around the edge. Re-wax and hot-press it into contact. If the Yeagley lap is being used, chip it off and make a new one. Be sure in polishing that the fingers do not curl over the edge of the mirror. They will warm and expand the edge, which polishes off, and when the mirror has stabilized, the edge is turned. Also, the fingers when hooked over the edge may impart an imperceptible tilt to the mirror in drawing it back from the end of a stroke, causing its edge to plow into the pitch, and thereby turning it.

Use short strokes if the edge is badly turned, otherwise the one-third stroke should bring up the diffraction ring around the left edge. Contact must be maintained. Work for five minutes and press with a weight for five minutes. After three or four such spells, test the mirror on the Foucault stand. The diffraction ring should be making an appearance. Cold-press on the lap for about 15 minutes before going ahead.

An excellent aid to securing contact in cold-pressing is the use of a piece of onion sacking. An empty onion sack can be bought at a vegetable store for a few cents. Spread a piece of it over the lap, lay the mirror on it and place a weight on top of the mirror. Keep the onion sacking in a covered jar, and rinse it out occasionally. It is not necessary to use it on the molded lap.

Turned-up Edge. This is a narrow edge zone of a shortened radius of curvature. It is conspicuous by a thin stripe of shadow just inside the diffraction ring around the right edge. The corresponding zone on the left edge is very bright. It seldom occurs in more than mild form, which usually works out under the long and overhang strokes used to correct the oblate spheroid or to parabolize. It may result from the short strokes used to correct a turned-down edge, or from trimming the lap to too small a diameter. If it is stubborn, polish upside down for two or three minutes, with short strokes. This will cause the edge to turn down, and some correction will be necessary to restore the diffraction ring.

When satisfied that the edge has been made right, go after the rest of the figure.

Correcting the Oblate Spheroid. This figure has a longer radius of curvature in the central area than at the edge. From our interpretation of the Foucault shadows (Fig. 15), this central portion has the appearance of a hill. To eliminate it, work the mirror on the lap so as to deepen the center. Properly done, a smooth, spherical surface should result.

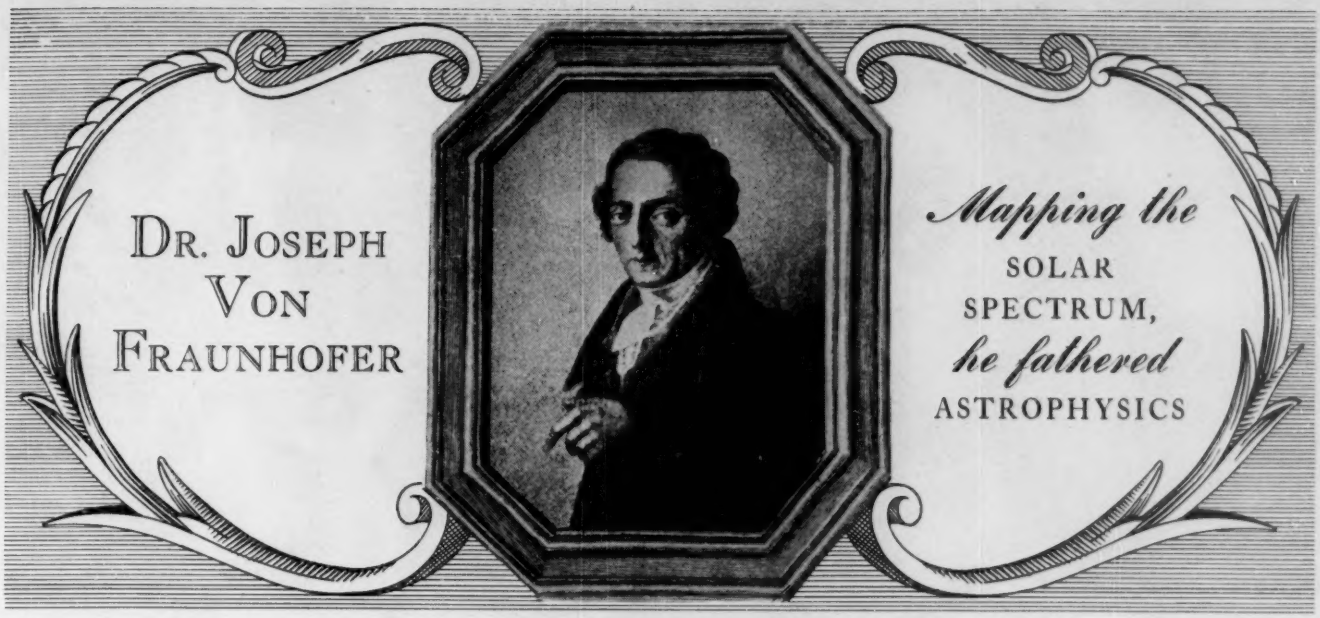
Hot-press for contact. Use a one-third to one-half diameter W stroke, extending the overhang on each side to the boundaries of the hill. Work and press in five-minute intervals, and test after two such spells. If the hill is being planed down evenly, restore the contact and continue with the same stroke. If a crater or hole is starting at the center of the hill, reduce the stroke length. If progress seems too slow, increase the length of stroke. As the hill reduces in size, shorten up on the stroke and pull in the overhang. Hard laps will permit a wider range of strokes than soft ones. If good contact is being maintained, the edge will not be impaired, and the blending overhang stroke will be ironing out any zonal rings that may have resulted from the short strokes of edge correction. Use of a rapid stroke will often bring a hill down fast, but look out for turning the edge. Finally, to wipe out any zonal irregularities remaining from the oblate figure, return to the one-third W stroke with an overhang of ½", cold-pressing frequently. Eventually, the mirror will be whipped into a spherical figure, and on the Foucault stand it will appear flat and velvety smooth from edge to edge.

Correcting the Hyperboloid. This is usually the result of overshooting the parabola, or too zealous work in reducing the oblate spheroid. In this figure, the radius of curvature of the center zone is shorter than it is at the edge. This is also true of the ellipsoid and the paraboloid. On the Foucault stand, the shadow boundaries on all of these figures are the same; only the shadow depths differ. As the difference in zonal radii increases, the depth of shadow increases (Fig. 16).

The cure here is similar to that described for correcting the hyperbolic figure that was ground into the mirror in Fig. 10. The edge zone must be worn down to the level of the curve of the center zone, and this is done with a short stroke. Unfortunately, we cannot control the distribution of the edge polishing so that the figure will emerge spherical. It will pop up as an oblate spheroid, which is dealt with as described.

Keeping Contact. It is all right to leave the mirror on the lap overnight if desired. Don't use any weight. Wrap a wet cloth around the disks to prevent evaporation, and the next day you are off to a flying start with perfect contact.

(To be continued. Next month the paraboloid will be described.)



WHEN Fraunhofer in 1814 added a telescope to Newton's glass prism and Wollaston's light-slit, he was able to locate 576 dark lines crossing the spectrum of the sun.

These Fraunhofer lines, as they are now called, could not be seen by Newton and were merely noticed by Wollaston.

The young experimenter tried prisms of various transparent materials, and found that the dark lines could not be due to the prism itself. Then he examined the spectra of the moon and the planets, and terrestrial objects shining by reflected sunlight. Since the lines remained in all cases identical as to number and position, he knew that they were not caused by the atmosphere. When he studied the spectra of the stars, however, he saw that although the colors appeared in the same order, the dark lines had changed position and intensity. The character of the light source itself, then, must somehow be responsible for the lines, and we know now that they are the fingerprints of the atoms.

Fraunhofer invented the diffraction grating, but before he could use it in extending his study of spectra, he died at the age of 39.

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